site technique—of the maturation stages in the ovum of the bat were placed before the congress by Prof. van der Stricht. Equally fine specimens, showing the manner in which the zona radiata is formed round the ripening egg of the rabbit, were shown by Regaud and Petitjean, of Lyons University. Their specimens showed that the zona radiata of the ovum is fibrillar in structure, and that the fibrils are arranged in an inner and outer zone. The fibrils are formed in the intercellular protoplasm in which the cells of the Graafian follicle are embedded. It will be thus seen that the zona radiata is not formed from, but deposited on, the ovum. Prof. Eternod, of Geneva, dealt with the manner in which the human ovum becomes implanted in the uterus, and the subdivision of the archenteron into the cavity of the amnion, the neurenteric canal and alimentary tract.

If one may judge from the nature of several contributions to this congress, there is a decided tendency to break down the barriers that separate the methods of the anatomist from those of the physiologist. Three communications dealt with results obtained by experiment on living animals. Prof. Sano, of Antwerp, by removing groups of muscles from the limbs and studying the subsequent changes in the motor cells of the spinal cord, sought to determine the position of the various motor centres in the cord. Prof. Tricomi, of Messina, used a somewhat similar method in investigating the paths of auditory impulses.

The members of the congress took part in the dedication of a monument to the memory of Prof. Hermann Fol, who set sail from Havre in his yacht, *l'Aster,* in the spring of 1892 to investigate the fauna of the Mediterranean. From the day he sailed until now not a single trace has been discovered of ship or crew. The members of the congress were lavishly entertained by Madame Fol. The congress placed a wreath on the bust of the Swiss physiologist Servetus, who discovered the pulmonary circulation in the sixteenth century, and was burned at the stake by Calvin because, so it is said, he denied the existence of the Trinity. A wreath was placed by the British section of the congress on the spot where he was burned, this gracious act being prompted by Prof. Dixon, of Trinity College, Dublin.

The congress was a social as well as a scientific success. An invitation from American anatomists to meet at Boston in 1907 was declined, as it was felt that at least a space of five years should intervene between each congress. A permanent committee for the organisation of the next congress was formed by the nomination of five men, one from each of the five affiliated societies. It is intended to bring out a bulletin containing the proceedings and transactions of the congress, to which purpose part of the sum (11,000 francs) raised by subscription in Geneva to meet the expenses of the congress will be devoted. When it becomes the turn of London to entertain this congress, it will not be found an easy matter to attain the standard of hospitality which has been set by Geneva.

PROF. T. R. THALÉN.

BY the death on July 27 at Upsala of Prof. Tobias Robert Thalén, Sweden has lost one of her most eminent physicists and teachers. He conducted investigations of great delicacy and value in the field of spectrum analysis, and was the assistant of A. J. Angström in much of his work. He also furnished valuable contributions to the knowledge of terrestrial magnetism, and devised ingenious methods of searching for iron-ore deposits. Born at Köping on December 28, 1827, he matriculated at the University of Upsala in 1849, where he graduated as Doctor of Philosophy in 1854. In 1856 he became lecturer on astronomy, and from 1856 to 1859 travelling scholarships enabled him to study in England, France, and Germany. In 1861 he was appointed assistant professor of physics at Upsala, and from 1869 to 1870 he was professor of physics at the Stockholm Technical School. In 1873 he was appointed professor of mechanics at Upsala, and in the following year was transferred to the chair of physics. This professorship he held until 1896.

The principal memoirs written by him dealt with the determination of lines in the solar spectrum (1860), researches on the magnetic properties of iron (1861), on the Fraunhofer lines (1866), spectrum analysis (1866), determination of the wave-lengths of metallic lines (1868), terrestrial magnetic observations in Sweden in 1869–71 and 1872–1882, researches on the spectra of metalloids (1875), the search for magnetic iron ore deposits (1877), and on the arc spectrum of iron (1885).

Prof. Thalén's researches on the spectra of metals and metalloids won for him wide renown, and are recognised as classical contributions to spectrum analysis. Partly in conjunction with Angström and partly by himself he produced accurate and elaborate maps showing the wave-lengths of the lines in the spectra of many elements. He also made a careful examination of the absorption bands of iodine vapour, and engaged himself on the difficult problem of determining and properly assigning the lines in the spectra of bodies of the yttrium and cerium groups. At the period when these papers appeared, precise measurements were needed to settle several fundamental questions in spectrum analysis, and the researches in which Prof. Thalén took part were of great assistance in this connection. The revised list of the lines in the arc spectrum of iron, published in a memoir presented to the Royal Society of Upsala in 1885, is still a standard work of reference wherever investigations in spectrum analysis are carried on.

The magnetometer invented by Prof. Thalén for searching for magnetic iron ore deposits greatly facilitated the work of prospecting, and there is not a single iron mine of any consequence in Sweden where this instrument has not been used. It was described in a paper read by Mr. B. H. Brough before the Iron and Steel Institute in 1887. In appreciation of the value of this instrument, in 1874 the Swedish Association of Ironmasters awarded Thalen a gold medal; and in 1884 he received the Rumford medal of the Royal Society for his spectroscopic researches. He was a member of the Swedish Academy of Sciences, and an honorary member of numerous scientific societies, both in Sweden and other countries.

THE SOUTH AFRICAN MEETING OF THE BRITISH ASSOCIATION.

THE various sections of the British Association met at Cape Town for three days last week, when presidential addresses were delivered and reports and papers were read and discussed. We print two more of the presidential addresses this week, and, following our usual custom, shall give in subsequent numbers other addresses, as well as reports of the proceedings of the sections written by members attending the meeting in South Africa. It is only necessary now, therefore, to refer to matters of general interest connected with the meeting.

On August 17 a special graduation ceremony in honour of the association was held at the City Hall. The degree of Doctor of Science was conferred upon:—Prof. G. H. Darwin, F.R.S.; Sir William Crookes, F.R.S.; Sir David Gill, K.C.B., F.R.S.; Prof. Porter, of Montreal; Prof. Davis, of Harvard University; Dr. Backlund, director of the Imperial Observatory, Pulkowa, Russia; Prof. Bohr, Copenhagen; Prof. Engler, Berlin; Prof. Kapteyn, Groningen University; Prof. Penck, Vienna; and Dr. Sjögren, Stockholm.

At the conclusion of the ceremony, the Vice-Chancellor, Sir John Buchanan, read the following telegram from the Prince of Wales, Chancellor of the university:—"I desire to offer my hearty welcome to the members of the British Association who to-day receive our honorary degrees.—GEORGE, Chancellor."

The members of the association arrived at Durban on Tuesday, and were publicly welcomed in the City Hall, the Mayor of Durban, who was in the chair, expressing his confidence that the meetings would prove beneficial to mankind by widening the boundaries of scientific knowledge and by inculcating a deeper interest in scientific research.

In returning thanks on behalf of the association, Prof. Darwin is reported by Reuter to have said:—

> It was exactly seventy years since His Majesty's ship *Beagle*, engaged in an historical expedition, sighted the coast somewhere about the latitude of Natal. At that time Durban was only a small village in the interior, entirely in the hands of the Zulus. It was a fact not hitherto recorded anywhere that his father, who was on board the *Beagle*, was anxious that Captain Fitzroy should put him ashore in order that he might make his way on foot or on horseback, or as best he could, to Cape Town. But it came on to blow, and the *Beagle* was unable to send a boat ashore. He felt that the chances which his father had of reaching Cape Town alive were so slight that he might say his presence on the platform that day was the result of a puff of wind.

The annual report of the council for the year 1904–5 was presented to the general committee at Cape Town on August 15. It is devoted chiefly to a statement of what action has been taken in connection with a resolution from the committee of the section of mathematics and physics expressing the opinion that the organisation of a Central Meteorological Department for the British Empire would be of the highest benefit to the progress of meteorological science and its application to the economic problems of the various colonies and dependencies. The resolution was referred to a committee consisting of Dr. A. Buchan, Dr. H. R. Mill, Dr. Shaw, and the general officers, to consider and report thereon to the council; and the memorandum drawn up by the committee and approved by the council on March 3 is abridged below:—

> There is at present no provision for the systematic treatment of the meteorology of the British dominions. Observations of various kinds are made in nearly all the British colonies and dependencies, and summaries of these observations are generally included in the respective official publications. India, Ceylon, Canada, the several States of Australia, New Zealand, Mauritius, the Cape of Good Hope, and the Transvaal have organised meteorological establishments and issue regular meteorological publications. Information with regard to the meteorology of the Crown colonies and protectorates is to be found in the Blue-books of the several dominions.
>
> There is no provision for the coordination of the methods of observing, the instruments employed, or the presentation of results. The want of a satisfactory system of coordinating the observations from the several dominions is to be deplored from two points of view—the economic and the scientific.
>
> From the economic point of view, it is eminently desirable that facilities should be given for the comparison of the climatic features of the regions available for settlement and the conditions which affect various industries. At present it is possible to obtain a certain amount of information for an individual colony by reference to colonial Blue-books, but the data are of very different orders of completeness; and to ascertain in which colonies specified climatic conditions are to be found would be a labour of such difficulty as to be practically prohibitive. The Board of Trade publish a certain number of tables of meteorological results among their colonial statistics, but something of a more comprehensive character is required. From the scientific point of view the regular issue of the meteorological data for the British colonies in a published and easily accessible form is urgently desired by meteorologists of all countries.
>
> But there is another aspect from which the scientific treatment of meteorological data must be regarded as having an important bearing upon the economic interests of remote parts of the Empire. Sir John Eliot, in his address to the British Association meeting at Cambridge, pointed out how the study of the meteorological conditions of the Indian Ocean and the bordering countries had been already applied to problems affecting the economic conditions of India as depending upon the variation of the monsoon rainfall, and he gave reasons for believing that the further prosecution of the inquiry promises valuable results for India, Australia, South and East Africa, and other countries bordering on the Indian Ocean if provision were made for dealing with the meteorological problem in a comprehensive manner with reference to the Indian Ocean as a whole.
>
> Similar reasoning may be held to apply also to other oceanic areas, in or on the border of which British colonies are situated. In this connection it should, perhaps, be mentioned that the control of the meteorological organisation of the British West Indies is already passing into the hands of the United States. As a result of Sir John Eliot's representation, the attention of the council of the British Association has been directed to the advantages likely to accrue from the organised study of the meteorological problems affecting various groups of British dominions.
>
> It has been further pointed out that such organised study can be most effectively secured by the establishment of a central institution devoted to these objects. Such an institution ought to be in close connection with the Meteorological Office, which is itself in regular correspondence with the meteorological organisations of foreign countries as well as those of the self-governing colonies. The meteorology of the ocean has been an essential part of the work of the office from its establishment in 1854, and oceanic data must necessarily be appealed to for the effective study of the meteorology of the neighbouring land areas.
>
> By way of summary, the objects of the suggested institution may be briefly stated to be:—
>
> (1) To give any information that may be required to the Governments or other authorities of the British dominions as to instruments and methods to be adopted for an effective system of meteorological observations.
>
> (2) To compile and publish periodical reports upon the climatic conditions of the various parts of the Empire upon a comparable plan. To form an accessible depository of information upon matters concerning the climates of the whole Empire, and to afford information upon those subjects to inquirers.
>
> (3) To provide a scientific staff for the study of the general meteorological conditions which affect the weather in the various British dominions, and in particular to promote the formulation of meteorological laws, and to apply them to explain and ultimately to anticipate the occurrences of abnormal seasons.

A copy of this memorandum was forwarded to the Colonial Office, with a covering letter suggesting that the question might be moved by a deputation to the Secretary of State. In reply, Mr. Lyttelton said that, whilst sympathising with the object which the council had in view, he did not think that there would be any advantage in receiving a deputation until he was in possession of further information on the subject. In satisfaction of this request, the committee drafted another memorandum dealing mainly with the object numbered 3 in the foregoing summary, because the services indicated under numbers 1 and 2 would be included incidentally in the development of number 3. This memorandum is as follows:—

The idea underlying the proposal is to deal with the general meteorological conditions of wider areas than those with which the various meteorological offices of the world have hitherto been regarded as being primarily concerned. The British Meteorological Office does indeed concern itself with the meteorology of the oceans from the point of view of shipping. In effect, the proposal is to utilise further the information already obtained at sea in conjunction with land observations for the investigation of the meteorology of large ocean areas in relation to that of the adjacent land areas, and from the point of view of the land population.

It is known, for example, that the meteorological conditions of India, Australia, South Africa, East Africa, and Egypt stand in close relation to those of the Indian Ocean, and the study of these relations promises very important results in connection with the prediction of the seasons. This investigation requires that the information shall be treated in a manner different from that now followed for the more immediate purpose of its application to the interests of shipping.

The meteorological phenomena which are regarded as demanding careful study, in the first instance, are the following:—

The conditions of favourable and unfavourable seasons in India.

The droughts of Australia and South Africa.

The conditions of favourable and unfavourable Nile floods.

With those would be associated the relation of the weather of the Mediterranean to the Indian cold weather anomalies, and the relation of the South Indian anticyclone to the Antarctic ice.

The larger part of the necessary land data for the investigation of these particular questions can probably be found in the publications of the meteorological organisations of India, Australia, South and East Africa, Egypt, Mauritius, Hong Kong, Singapore, or can be furnished directly by those organisations. They should be supplemented by observations contributed by certain foreign Governments. The marine data would have to be compiled from the documents collected from ships by the meteorological departments of this country and India. The further development of the collection of observations—more especially of marine data—might be necessary, in order to complete the investigation.

The use of the data would be, in the first instance, to obtain a survey of the sequence of the more general weather changes over the whole region under consideration. The first step in the operations therefore would be to consider the nature and extent of the data available for the purposes in view, and the form in which they should be compiled for study or for publication.

A corresponding inquiry for the Atlantic Ocean and the countries bordering upon it is equally desirable, and should be conducted concurrently in the interests of the British Isles and the American and West Indian colonies.

In order to carry out the proposal, something more than what would be generally understood by "a moderate addition to the staff of the Meteorological Office" is required. The proposal involves a scientific investigation of a very important character which could not be regarded as merely an incidental addition to the usual operations of the office. A man of suitable scientific attainments should be responsible for conducting it in consultation with, and under the general supervision of, the director of the Meteorological Office. It is desirable to mark the nature of the qualifications expected in the person to whom the work is entrusted by giving him the title of assistant director, and providing a salary of from 400*l.* to 600*l.* a year. It should be remembered also that the Meteorological Office could not find accommodation for the proposed additional staff without some addition to the space at present available.

It is estimated that the annual cost of the work would be 2000*l.*, rising in five years to 2500*l.*, made up as follows:—

	£		£
Salaries: Assistant Director	450	to	550
Scientific assistant, computers and clerical staff	1,050	to	1,300
Publications, printing and stationery ...	300	to	500
Incidental Expenses, office rent, &c. ...	200	to	150

The estimate is based on the supposition that the Meteorological Committee would be willing to undertake the general control of the department as a branch of the Meteorological Office.

It may be mentioned that the Government grant to the Meteorological Office at present stands at 15,300*l.* The cost of the marine department, as shown in the report of the Meteorological Council for 1903–4, is 1366*l.*, exclusive of office expenses, publications, &c.

The council, in approving this memorandum, has caused it to be conveyed under a covering letter to the Secretary of State for the Colonies.

SECTION C.

GEOLOGY.

OPENING ADDRESS BY PROF. H. A. MIERS, M.A., D.Sc., F.R.S., PRESIDENT OF THE SECTION.

IN opening the proceedings of Section C in its first visit to South Africa, and speaking first on behalf of those who are visitors, I think I may justly claim that to no Section of the British Association can this visit be more interesting or even more exciting than to us; we enter for the first time a country the geological features and history of which, and the mineral productions of which, have long aroused the keenest interest among European geologists and mineralogists.

We have followed the discoveries and discussions of South African writers; we have read your views and have become familiar with your terminology; we have heard the reports of those who have visited the country, either as travellers or with the special object of investigating its geological problems or mineral resources; and, indeed, ever since the Geological Society of London received the historic papers of Andrew Geddes Bain, the father of South African geology, many of the memoirs of your own geologists have been communicated to European societies and journals; we have looked from afar with yearning eyes upon this alluring country; and at length we have found ourselves upon its shores.

It has not been given to many of us to see those great pioneers of South African geology whose work was done in the days before amateurs and experts could come out for a few weeks or months to take a hurried survey of the country; but their enduring labours, which have laid the foundation of all subsequent work, are well known to us, and it is not necessary for me to do more than mention the familiar names of Bain, Wyley, Stow, Atherstone, Sutherland, and Dunn. Of these only the last named survives; but when one remembers that his maps of North Cape Colony and of Orange River Colony have served as the basis of the maps now in use, one is reminded how recent is the whole history of South African geology, and how much was achieved in so short a time by these early workers.

It is exactly one hundred years since John Barrow wrote the concluding words of his "Travels in South Africa" which first directed attention to the geology of this country; it is only fifty years since Bain sent home the manuscript of the classic papers to which I have already alluded.

Since their days many have been the scientific visitors to the country who have remained here for longer or shorter periods, whose works have made us familiar with its problems and have contributed to their solution; the names of Cohen, Draper, Exton, Gibson, Green, Griesbach, Passarge, Rubidge, Sawyer, Schenck, and Seeley recall some of the most substantial scientific work which has been done either by visitors or residents. Several others who, without visiting the country, have by their researches in Europe helped to unravel the problem of South African stratigraphy were enumerated by Dr.

Corstorphine in his interesting and exhaustive Presidential Address last year.

If we must regret that we never had the opportunity of seeing the great pioneers and the earlier workers, we may rejoice that we have been able to meet those who are now actively engaged in continuing their labours; the period of cursory visits and fragmentary essays is closing and the era of deliberate and systematic surveys is beginning; we now look for authoritative information to the Cape Survey inaugurated by Dr. Corstorphine in 1895 and so ably continued by his successor Mr. Rogers; to the Transvaal Survey begun by Dr. Molengraaff in 1897 and auspiciously revived under Mr. Kynaston; and to the Natal Survey which Mr. Anderson has so successfully directed since 1901. I hope that it will not be long before there is no part of South Africa outside the direct supervision of a systematic and well-ordered survey.

There is perhaps some danger lest in a developing country, where the commercial possibilities are prominently before all eyes, the immense importance of such surveys should be overlooked, and lest it should be thought that what appears to be purely scientific research may be left to take care of itself until the mineral wealth of the country has been explored. I cannot enter too emphatic a protest against such a view; how closely the two interests are knit together must be apparent to anyone who reflects that the nature and sequence of the more northerly formations which have yielded coal, diamonds, gold, and metalliferous deposits can only be studied in the light of the more intelligible geology of Cape Colony and Natal. It is, moreover, immensely to the advantage of South Africa that you have intimately connected with the mining industry geologists of such training as Doctors Corstorphine, Molengraaff, and Hatch, who have all gained valuable experience upon geological surveys.

I may now, perhaps, cease to speak merely as a representative of the visitors and identify myself more closely with the Section as a whole; for the most gratifying feature of this meeting is that it is not merely a visit of strangers who are enjoying your hospitality, but that with Section C of the British Association is fused Section B of the South African Association, so that for the time being we are all colleagues; and even such vexed questions as the correlation of the rocks of the Transvaal or of Rhodesia with those of the Cape, or the origin of Banket, or of Blue Ground, or the extension of the Main Reef Series (perhaps it is no longer necessary to include the problem of the Dwyka conglomerate) can be discussed by us on the spot as members of the same body inspired by the same earnest desire for truth.

I began these preliminary remarks by asking that I might be regarded as the spokesman of the visitors, and therefore represented myself as a geologist visiting the country for the first time. I must, however, make a frank confession. Not only is this my second visit to the country, but I have not even any claim to be called a geologist. My training and experience have been such that upon many of the questions which must be most interesting to this Section I am not competent to form an opinion or to appreciate properly the evidence. I must, therefore, crave your indulgence if in this Address I refrain from discussing any of the problems of surpassing interest which naturally engage the attention of those who are occupied with the study of South African geology. It would indeed be an impertinence for me to do so.

I venture, however, to hope that the frontier between geology and mineralogy is so ill-defined—if indeed a scientific frontier can be said to exist—that the thoughts and occupations of one who has confined himself to the study of minerals, and that rather in the laboratory than in the field, are not alien to the interests of Section C.

Experimental Geology.

A somewhat lamentable aspect of modern science is the vast array of unorganised facts which are awaiting coordination; this is too often because they have been amassed without any definite idea of the purpose which they may serve; consequently it may happen that laborious observations belonging to one science may fail to attract the regard of a neighbouring science merely for want of the mutual acquaintance which would make them serviceable to each other; and in these days of exclusive specialisation the introduction which might lead to a happy union is, perhaps, not brought about for years. None can be more fully alive to the importance of such an alliance than those whose work lies on the borderland between different sciences; the mineralogist, for example, is in contact on the one side with the experimental sciences of chemistry and physics, and on the other with geology, which has scarcely yet entered the experimental stage. He cannot fail to be impressed by the need of the appeal to experiment on the geological side of the border, and it is perhaps his duty to supply the want so far as lies in his power.

Owing to this very need some of the most difficult problems in geology are those concerned with the origin of minerals and of the rocks which they compose. One need but recall the many theories which have been held about the origin of mineral deposits, the filling of metalliferous veins, the local concentration of certain minerals, the distribution of various rock types, the existence of rock magmas of diverse compositions, and the differentiation of their constituents. Could the importance and difficulty of such problems be better illustrated than in South Africa, and by its two most valuable minerals, gold and diamond?

Now all these are problems in which direct appeal may, and indeed must, be made to laboratory experiments; the well-defined minerals of which the earth's crust consists do not, after all, number much more than 800, and of these many have already been manufactured in the laboratory. Speculation upon the origin of rocks and minerals should surely be controlled by the results of experiments, and equally should experiment which is to be of service to geology be guided by a knowledge of the problems to which it is to be applied. It will be my object in the present Address to illustrate these principles by examples drawn from recent experimental work which can be applied to geological problems, and to indicate the course which such research is likely to pursue in the immediate future.

It seems to be sometimes expected of a Presidential Address that it should contain a summary of the progress of a science during past years, and this is no doubt very useful and instructive; but if we are to go forward in our scientific work we must not be satisfied with the patient accumulation of details, or content to congratulate ourselves upon the number of them which have been amassed. I venture to think that it is more profitable to take our stand upon the actual work of to-day, and from that tower of observation to look forward to the future rather than backwards to the past; to exclaim with the poet—

> "No, at noonday in the bustle of man's work-time
> Greet the unseen with a cheer!
> Bid him forward."

It would be interesting enough to trace the history of the artificial reproduction of minerals, beginning with the famous experiment of James Hall; to follow the lines that led to the development of the French School during the last half of the nineteenth century; to dwell on the researches of Senarmont, Ebelmen, Daubrée, and Sainte-Claire Deville; to show how the increasing study of petrography and the invention of the electric furnace have led to renewed activity in the attempts to reproduce igneous rocks and the rock-forming minerals; to discuss the more modern experiments of Fouqué and Lévy, Lagorio, Loevinson-Lessing, and Morozewicz; or to describe the manufacture of many an interesting mineral by de Schulten and others who are actively prosecuting research of this nature, including such sensational achievements as the production of the ruby by Frémy and of the diamond by Moissan.

Instead, however, of attempting a survey of all that has been done, or even of all that is being done in the artificial reproduction of minerals, let me adhere to the principle that I have laid down, and discuss only a few of those researches, now being carried on, which promise to be most fruitful because their methods and aims are inspired by the discoveries and views of modern chemistry and modern physics.

Van 't Hoff's Work on the Salt Deposits.

Among such researches the most remarkable are those conducted by Prof. van 't Hoff and his pupils during the last eight years upon the Stassfurt salt deposits. These deposits are of enormous extent, more than 1000 feet thick, and consist of fairly well-defined layers of various sulphates and chlorides of sodium, magnesium, and potassium, and their double salts and hydrates. It has long been supposed that the minerals have been derived from the evaporation of sea-water which contains in solution the chlorides of sodium, magnesium, and potassium, with sulphate of magnesium and small quantities of calcium salts; and the general sequence of the minerals is that of their solubility; the less soluble sodium chloride crystallised out first and is at the bottom, while the very soluble magnesium chlorides, having been the last to crystallise, occupy the top of the series. But the problem is by no means so simple as to be one of mere solubility in water; the rock salt itself persists through the whole series, and some of the associations are difficult to explain.

As is well known, the modern theories of solution mainly rest upon the behaviour of dilute solutions from which the principles of electrolytic dissociation have been deduced; but in the case of the concentrated solutions from which dissolved substances actually crystallise, very little is really known about the liquid itself. A great deal is known, however, about its equilibrium with the solids that separate from it, and the general laws of this equilibrium are expressed by the phase-rule deduced from mathematical considerations by Willard Gibbs, which states how many mechanically separable constituents can coexist under varying conditions of equilibrium in a system containing a definite number of chemical components.

A solution saturated with a given substance is one which is in equilibrium with that substance when the latter is in contact with it in the solid form; the phase-rule indicates the number of solids which must be in contact with a given solution; the only difficulty in practice is to determine the nature of the double salts or distinct hydrates that may be formed.

By means of a series of experiments upon the solubilities of these salts, either singly or in the presence of one another, in order to determine the composition of solutions saturated simultaneously with two or more substances, it is possible to obtain a graphic representation of all possible solutions containing the salts present in sea-water. From this the course of crystallisation of any particular solution, for example sea-water, can be predicted.

The general sequence thus theoretically predicted is as follows:—(1) Rock salt; (2) Rock salt with the magnesium sulphate, epsomite; (3) Rock salt with the double sulphate of potassium and magnesium, leonite; (4) Rock salt with leonite and the potassium chloride, kainite; (5) Rock salt, the magnesium sulphate kieserite, and the double chloride of potassium and magnesium, carnallite; (6) Rock salt, kieserite, carnallite, and the magnesium chloride, bischoffite. This last combination will persist until all the water is evaporated. This is found to be the general sequence, not only of the salts obtained on evaporating sea-water at 25°, but also of the Stassfurt deposits.

Up to this point the results have been summarised by Dr. E. F. Armstrong in a report presented to the British Association in 1901. Since that date the research has been prosecuted actively by van 't Hoff and his pupils, and now the conditions of equilibrium at 25° have been mapped out, not only for the above compounds, but also for the minerals thenardite, glaserite, astrakanite, and reichardtite, which occur in these deposits. The whole process of crystallisation of the solution, from which no fewer than twelve different salts have separated, can, therefore, be predicted, and their sequence and associations can be traced through numerous stages, beginning with the separation of rock salt and ending with a mixture of rock salt, kieserite, carnallite, and bischoffite.

In reconstructing the history of these deposits account must also be taken of the varying vapour pressures of the solutions which are saturated with the different compounds, as this really determines which particular compounds are stable, so that the matter is by no means so simple as might appear from this brief sketch. It is further necessary, in order to bring the process within reach of calculation, to assume that each deposit is removed from contact with the mother liquor after it has crystallised out; but fortunately this is practically what has happened in the Stassfurt deposits, for each layer is more or less separated from the succeeding one by an intervening layer of clayey material.

It may be possible even to go a stage further and obtain a clue to the actual temperatures that prevailed, for two minerals, langbeinite and löweite, are absent from the theoretical model made by van 't Hoff to represent what must happen during evaporation at 25°; and this indicates that while the deposits crystallised the temperature really rose higher than 25°, probably as high as 43°; in fact, after the conditions of equilibrium have been worked out, the appearance or disappearance of certain minerals can be used as a sort of geological thermometer, capable of indicating the limits within which the temperature can have varied.

The whole investigation is a splendid example of experimental research devoted to a particular problem and directed by a well-established theory; the chemist in his laboratory has now succeeded in tracing the changes that took place ages ago in the bed of a land-locked sea as it laid down its contents and finally became a dry basin, although he is not able to reproduce the original conditions or to work for the long periods which Nature had at her disposal. Without the logical consideration of the conditions necessary for equilibrium, countless experiments might be made upon these salts, and an immense amount of speculation might have been devoted to their possible reactions in the liquid state, about which we know so little, instead of to their equilibrium when solidifying, about which we know so much more.

Some Petrographical Problems.

The other geological problems which I have mentioned have also been beyond the reach of actual experiment, for it is hopeless to attain the immense pressures and high temperatures or the enormous time that may have been required for the growth of natural minerals in rocks and veins; and so when difficulties are encountered there is a tendency to "explain" them (if the word may be so misused) by reference to the mysterious effect of conditions which cannot be brought directly within the reach of experiment.

I cannot help thinking that this has to some extent occurred in the discussion of the petrographical problems which I propose to consider next. There are two great liquid reservoirs from which minerals have crystallised—the sea, with its dissolved salts, and the subterranean baths of molten silicates, from which the igneous rocks have been derived. It is true that in the sea two of the constituents, water and sodium chloride, largely predominated over the others; but, after all, both sea and lava are liquids subject to the same physical and chemical laws.

An admirable summary of the evolution of petrographical ideas was given in the Presidential Address to the Geological Society of London in 1901 by Dr. Teall, who dealt both with the consolidation of rocks from molten magmas and their differentiation into species. It is not, therefore, necessary for me to consider anything but recent work which has been done during the last four years, and the earlier controversies may be left out of account.

Among the many problems relating to the mineral and chemical constitution of rocks which have yet to be solved, two, and those perhaps the most important, should lend themselves most readily to experimental treatment. The first is the problem of rock differentiation: why does a magma, even one which has presumably crystallised *in situ*, separate itself into zones, or layers, or streaks of different constitution? And the second is the problem of mineral differentiation: why does a granite magma, for example, crystallise as a mixture of the particular minerals mica, felspar, and quartz, and why is the least fusible mineral the last to crystallise?

It will scarcely be possible for me to deal in this Address with more than the second of the two problems, but it will be apparent from the somewhat parallel case of the salt deposits that the mere order and manner of crystallisation of a mass of molten silicates must be a sufficiently complex problem to exhaust our attention for the present.

Magmatic Differentiation.

If we are to consider only recent experiments which have a bearing upon the problems of rock magmas, it is not necessary to say much about the first great petrographical problem, that of the differentiation of magmas into various rock types; for in this connection very few experiments have been made, and practically none of recent date. Observations of the facts as they present themselves in the field accumulate every day; almost every important petrographical region is being studied with the particular object of determining the mutual relations of its rock masses and the factors which have contributed to their differentiation. They have been ably discussed by Becke, Brögger, Becker, Cole, Harker, Iddings, Judd, Lacroix, Lévy, Pirsson, Rosenbusch, Teall, Washington, Zirkel, and many others; appeal has been made to the action of gravity, of temperature differences, of diffusion, of electric currents, of fractional crystallisation, of re-fusion, of chemically combined water, of absorption of the country rock; but with the exception of a single case, observed in the glassworks of Targowek, in which the top of a molten glass was found to contain less lime and more silica than the bottom, and some observations by Doelter upon boron-glass, there is scarcely a single experiment upon silicates which really bears directly on the question. That artificial glasses are far from homogeneous is known to glass-workers and to makers of lenses, but there is nothing comparable with the splitting of a magma into two or three distinct liquids which solidify as different rocks.

It is in the case of laccolites that the problem ought to present itself in the simplest form, for we may regard them as basins of igneous rock which have been practically imprisoned within solid walls and have crystallised *in situ*. There can, I think, be no doubt that differentiation has generally taken place even in such basins, that the margins have often a different mineralogical and chemical constitution from the more central portion, and that the differences are greater than can be accounted for by solution of the enclosing rock, and are often of a chemical nature which cannot be so explained.

The various theories that have been propounded fall into two distinct classes—those which seek the cause in the separation of solid material from the liquid, so that when the latter subsequently crystallised it constituted a different rock from the former; and those theories which assume that different liquids have separated from each other and then solidified as different rocks.

The first conception satisfactorily explains the manner in which the least soluble minerals are concentrated at the bottom or margin of an igneous mass, for they naturally crystallise first where the mass is coolest, or where contact with other crystals may have occurred; or even if they have been precipitated as a cloud throughout the magma they must be carried about by convection currents and ultimately sink together unless the magma be very viscous. Most geologists will probably agree with the conclusions of Vogt that some of the most important deposits of metals, metallic oxides, and sulphides have been produced by magmatic differentiation from deep-seated magmas which now constitute basic rocks associated with them. But this does not explain how the mass which has crystallised out may be not a mineral but a rock.

The actual observations on crystallising solutions do not amount to much; it is quite clear from laboratory experiments that crystals do grow by means of convection currents, which produce a flow of stronger solution towards the crystal and of weaker and warmer solution upwards and away from the crystal. The concentration currents can easily be seen in any ordinary aqueous solution as streaks in the liquid. Again, that there might be a slight difference in the concentration of the upper and lower, or of the warmer and cooler parts of a solution has also been shown. That a very considerable difference in concentration can be produced by centrifugal action was proved only last year by the experiments of Calcar and de Bruyn, in which solutions contained in rapidly rotating vessels became more concentrated in the portions furthest from the axis of rotation.

Schweig has recently suggested that the crystals which fall to the bottom of a rock-magma may be unstable compounds, which re-dissolve when the pressure is relieved, and so give rise to an underlying magma of different chemical constitution.

Harker, also, some time ago, suggested the existence of horizontal layers of different liquid magmas above each other, thus attempting to explain the presence of quartz in basic rocks as due to the crystals which had sunk into the basic magma from a more acid magma floating upon it.

The second theory, that of liquid differentiation, regards such layers as actually produced by the spontaneous division of a magma into two liquids of different composition, and if it be tenable seems more capable of explaining the geological facts.

The experiments bearing on the subject are well known, and have been quoted by Bäckstrom and Teall; mixtures of phenol and water, or of aniline and water, which form a homogeneous solution above a certain temperature, may below that temperature (which is a sort of critical point of the solution) divide into two solutions, one consisting of phenol in excess of water, the other of water in excess of phenol; and these two solutions are not miscible, but separate into two distinct layers.

Many pairs of substances have now been found to exhibit this incomplete miscibility, which varies with the temperature and may at certain temperatures become complete; among them are some of the metals such as zinc, lead, bismuth, and silver.

If rock-magmas can really behave in this way, there is no difficulty in explaining their differentiation; but experiments upon fused silicates have not disclosed anything of the sort, though they are made far below the critical temperature.

The case of nicotine and water, which has recently been described by Hudson, is remarkable and suggestive: above a temperature of 205° a mixture in equal proportions is a clear liquid; at 205° it divides into a saturated solution of nicotine in water floating on a saturated solution of water in nicotine; at 90° these two layers change places; at 64° they mix again and the liquid becomes once more homogeneous.

It is, of course, possible that fused silicates at experimental temperatures correspond to nicotine and water below 64°, and that rock-magmas correspond to the same mixture at higher temperatures.

In discussing the reasons why in laccolites of the Square Butte type the margin should be more basic, and in laccolites of the Magnet Cove type more acid than the centre, Washington regards the magma as a mutual solution of an alumo-alkaline substance with a ferro-magnesian substance; whichever of these is in excess may be regarded as solvent, and crystallises first, for example, either the syenite or the shonkinite. In a laccolite where no differentiation has taken place, as in the Henry Mountains type, he supposes the mixture to be eutectic or such that they crystallise together. Pirsson, in a paper recently published upon the "Highwood Mountain Laccolites of Montana," while attributing a greater part in the process to the action of convection currents, also regards the ferro-magnesian minerals, taken together, as constituting the solvent and crystallising first as shonkinite.

In fact, stated quite baldly, these latest views tend to a compromise between the two theories which I have just mentioned. They regard the splitting of the magma as produced by a fractional crystallisation, only now the mass which crystallises is not a mineral but a rock; in other words, they assume that rocks may be dissolved in each other, and may crystallise from each other as though they were minerals.

In this matter of magmatic differentiation, then, there has been during the last few years a large accumulation of geological evidence, a little new speculation, but practically no new experimental work, and scarcely any progress.

Mineral Differentiation and Eutectics.

Let us pass to the second petrographical problem, that of mineral differentiation, the nature and order of the minerals which crystallise when a cooling magma becomes a solid rock mass.

It has been laid down by Rosenbusch, and is accepted as a general rule (in spite of many exceptions), that the order in which the various minerals crystallise is one of increasing acidity, ores and oxides and so-called accessory minerals first, then those minerals which are comparatively poor in silica, then those which are richer and finally, if it be present in excess, the silica itself. It has also been supposed that the order may be one of the fusibility of the various minerals under the conditions of their formation; the least fusible minerals being the earliest to crystallise, and the most fusible the latest. Interesting speculations concerning the melting point of quartz at high pressures, and its consequent order of crystallisation, have, for example, been published recently by Stromeyer and Cunningham.

It is not necessary, however, to regard the molten magma as a mere mixture of fused minerals which solidify more or less independently and consecutively; it is more reasonable to regard the whole magma as a solution in which the various minerals are dissolved, and from which they crystallise as it cools. Now the temperature at which a substance separates from solution is generally far below its melting point, and the order in which the constituents of a mixed solution will crystallise is the order of their solubility in it, and bears no direct relation to their fusibility or to their chemical composition.

Teall in 1901, after discussing the controversies and the evidence on which they are based, came to the conclusion that rock-magmas are solutions, and that the order in which the minerals consolidate depends upon the nature of the constituents and their properties, and is not by any means the order of their freezing points. As to the particular minerals which crystallise, he thought that the molecular grouping in the magma is determined by mass action and by the mutual affinities of the bases, the silica, and the alumina. Concerning future research he ventured to predict that the next advances were to be made by experiment controlled by the modern theory of solutions.

Thirteen years earlier Teall had himself contributed a valuable suggestion based upon Guthrie's work on cryohydrates. When a mixture of nitrate of lead and nitre is fused and allowed to cool, the constituent which is in excess will crystallise out as from a solvent until the proportions left in the liquid state are 47 of lead-nitrate to 53 of nitre, and this mixture will then solidify at 207°, not as a uniform compound, but as an intimate mixture of the two salts, the *eutectic*, which crystallises at the lowest possible temperature, and is the only mixture which has exactly the same composition as the liquid from which it solidifies. Teall made the illuminating suggestion that micropegmatite is an eutectic consisting of quartz and felspar, and represents in certain rocks the final mother-liquor from which the other minerals have crystallised out. Eutectics in metallic alloys have been much studied during recent years: in the Address of 1901 Teall was able to strengthen his case by showing that spherulitic and micropegmatitic structures found in obsidian and other acid rocks are paralleled by similar structures developed in eutectic alloys, according as they have been rapidly or slowly cooled.

In the following year appeared a theoretical paper by Meyerhoffer concerning the ideal case of a molten mixture of two substances, a and b, which do not suffer double decomposition, nor form a double salt, nor an isomorphous mixture.

Let a diagram be constructed, with temperatures as ordinates and composition of the magma as abscissæ, giving by a curve the nature of the magma which is in equilibrium with either solid a or solid b. The curve has the form of a V; one arm represents the temperature and constitution of the liquid which can be in equilibrium with a, and the other that of the liquid which can be in equilibrium with b; and the lowest point corresponds to the eutectic, which is in contact with both.

Let a point above the curve represent the temperature and constitution of the liquid magma containing excess of b; as the magma cools this point descends to the b branch and travels along it while b is crystallising out, until the eutectic point is reached, when a and b both crystallise out together at a temperature below the melting point of either. The order of crystallisation is therefore determined solely by the composition of the magna as compared with that of the eutectic. If, however, the liquid be cooled slowly, crystallisation may be postponed until it has become supersaturated with regard to one constituent or the other, or both; a state of affairs represented by a prolongation of the arms of the V below its lowest point, and then the order of the crystallisation may be inverted.

In a rock-magma there are of course many other factors to be taken into account as determining the order in which the minerals separate; for example, the formation of both double salts and isomorphous mixtures, the possible production of unstable solid compounds which may become converted into stable compounds or may be re-dissolved soon after they have come into existence; and also the relative velocities of crystallisation, changes of temperature and pressure, action of steam, &c.; but the principle laid down by Meyerhoffer must be that which controls the process.

It might be objected that on this hypothesis the consolidation of every rock-mass ought to terminate with an eutectic mixture, whereas this appears to be by no means the case; in fact, it is only among some acid rocks that structures much resembling the eutectic mixtures of alloys are to be found. On the other hand, if the conditions of cooling are such that the magma becomes supersaturated with one mineral after another, it will overshoot the eutectic composition before each crystallises, and the final consolidation may be a well-marked sequence instead of a simultaneous crystallisation.

The controversies which have raged concerning the classification of rocks and their nomenclature appear to me to contribute little to the real advancement of knowledge. There are, I think, two more profitable lines of research which should accompany each other. We may take the facts as we find them and endeavour to explain them by the known laws of solutions aided by the phase-rule, provided that we have good reason to believe that rock-magmas behave like solutions, and we may make experiments upon slags and fused silicates and ascertain how far they resemble natural rocks in their behaviour and their mineral constitution. Some of the workers in this field have been led to regard rock-magmas as undoubtedly similar to ordinary solutions; others hesitate to seek an explanation for their features in the laws which govern the solutions studied in the laboratory. The two views are represented in the persons of the two men whose names are most closely identified with recent experiments, Vogt of Christiania and Doelter of Graz.

Doelter's Work on Melting Points and Solubilities.

The labours of Doelter and his pupils have been largely devoted to the melting points of the rock-forming minerals and their solubility in silicate magmas. From experiments upon these minerals and their mixtures they have come to the conclusion that in many cases the melting point of the mixture is about the mean of the melting points of the constituents, and that in such cases, therefore, there is no evidence that the freezing point is lowered, or that an eutectic mixture is formed; so that it is not safe to apply the theory of cryo-hydrates to fused mixtures of silicates.

Doelter is therefore led to regard the silicate-magmas rather as mixtures of various constituents which may be dissolved in each other, but which are not by any means necessarily identical with the minerals which separate on cooling. The whole process seems to him to be far too complicated to be explained by any such simple principle as the mere relative proportions of the various constituents to each other and to their eutectic mixture; the order of crystallisation must be determined by a number of factors, such as temperature, velocity of crystallisation, the interval between the softening and fusing of each mineral (which he finds to be considerable), viscosity, capillarity, the presence of water and mineralising agents, and the absorption of adjacent rocks.

To choose a simple example: minerals such as zircon, corundum, and titanite separate for the most part early, because they are less soluble. On the other hand, magnetite is one of the more soluble minerals, and yet it is one of the first to separate; the same is to a certain extent true of augite, but not always. It is possible that in a magma which still contains the iron of the magnetite in solution plagioclase and augite may be comparatively soluble and magnetite comparatively insoluble, but that when magnetite has already crystallised out from the magma the plagioclase and augite may be comparatively insoluble; the experiments which are wanted are experiments upon the solubility of certain minerals in magmas of known composition under known conditions; in these and similar instances the order of separation is that of the solubility, but such physical factors as the velocity of crystallisation (which varies very considerably with the temperature), and the viscosity, may completely invert the order.

Direct experiments made by Barus and Iddings upon the electric conductivity of silicate magmas afford evidence that such magmas contain dissociated as well as undissociated molecules, so that they cannot be regarded as merely fused mixtures of certain minerals. If two or more rock-forming minerals be fused together it may happen that they form new compounds and crystallise out as different minerals, or if one or the other remains unchanged it may crystallise out in a different proportion. All this shows that double decomposition goes on in the liquid. We cannot therefore expect, without knowing the degree of dissociation, to make much use of the lowering of the freezing point in order to calculate the other factors in the process of rock-formation.

Doelter concludes that upon the whole the normal order of crystallisation in rocks is in the main that laid down by Rosenbusch long ago, namely, an order of increasing acidity, but that it is determined by the mutual affinities of the molecules in the magma, and by the relative power of crystallisation of the components into which they unite themselves, and that the physical factors which I have already enumerated play a very important part in the process. No one has endeavoured more systematically than Doelter to determine for the rock-forming minerals the melting points and the solubilities, without which it is impossible to make much progress in our reconstruction of the history of rocks. He has recently shown us how the microscope may be used in the study of fused silicates at high temperatures, and has so opened up a new field of research.

Vogt's Applications of the Laws of Solutions.

The work of Vogt has extended over many years, and is now summarised in two remarkable memoirs recently published by him, in which are expressed his mature opinions upon silicate magmas; the reasoning is based upon his own experiments, upon those of Doelter, and upon the classic researches of Ebelmen. It is now generally conceded that the particular minerals produced in a silicate magma depend much more upon the chemical composition of the magma than upon temperature and pressure; Lagorio and Morozewicz were led to this conclusion by their own experiments upon fused silicates. Experiments upon slags at ordinary temperatures and pressures may, therefore, be invoked to elucidate the formation of rocks.

In 1902 Vogt stated his conviction that the laws of solutions may be applied to igneous rocks, and his two recent memoirs are, in fact, an attempt to explain the experiments upon slags and fused silicates as examples of the operation of these laws.

All important, according to him, is the composition of the eutectic mixture; he finds that if the analyses of silicate magmas be arranged according to their oxygen ratio or acidity, the various minerals of which they consist make their appearance within fairly well-defined limits. For example, in the case of the Ca-Mg-Fe-Mn slags, which contain little alumina, olivine and the melilite minerals only make their appearance in the more basic slags, and the metasilicates in the more acid, the limit between the two corresponding to an acidity of about 1·6.

The limit of individualisation between the various minerals is supposed to correspond to their eutectic mixture. Such slags may, therefore, be regarded as a mutual solution of two or more of the minerals olivine, enstatite, hypersthene, augite, the gehlenite-melilite group, akermanite, wollastonite, and the hexagonal metasilicate, which is so characteristic of the more acid slags. The particular minerals which make their appearance are practically determined by the acidity of the magma and by the relative proportion of the bases present, particularly by the ratio of the calcium to the magnesium-iron-manganese group; in other words, Vogt asserts that a silicate magma is a mutual solution of the various crystalline compounds that actually make their appearance as it solidifies, and that the order of crystallisation depends upon their proportion in the magma as compared with their proportion in the eutectic. The old conception of a solvent and a solute ceases to have much meaning; the matter which is of supreme importance is the nature of the eutectic mixture when the constituents are given; thus micropegmatite and microfelsite represent the eutectic of felspar and quartz, and correspond to a mixture of about 74 parts of felspar to 26 of quartz, as indeed has been stated by Teall.

Now, if we are justified in regarding rock-magmas and fused silicates as mutual solutions of certain definite compounds, and if these compounds are actual minerals or other silicates which crystallise out of the magma when it cools, we are also justified in making use of the properties of these minerals when we apply to the magma the known physico-chemical laws which govern solutions.

The number and nature of the minerals which can be in equilibrium with each other and the solution are to be determined by experiments upon their solubility interpreted by the phase-rule of Willard Gibbs, and especially by the laws which Roozeboom and other physical chemists have deduced for components which form double salts or isomorphous mixtures. Knowing the components we ought, therefore, to be able to determine their latent heat of fusion, their specific heat, the lowering of the freezing point of their mixtures, and from these data to calculate the true formulæ of the rock-forming minerals. It will readily be understood that in a mixture of quartz and orthoclase, the lowering of the freezing point below that of either of the constituents, as calculated by van 't Hoff's formula, from their melting points, latent heats, and molecular weights, will be very different according as the formula of quartz is taken to be SiO_2 or Si_3O_6.

Vogt boldly attacks the whole problem as one that can be solved on these lines; we have good reason to believe that the slags and rock-magmas are solutions; we know their constituents; we can therefore proceed to experiment with these constituents and to predict the behaviour of their mixture according to the principles of physical chemistry. The order of crystallisation is mainly determined by the relative composition of the magma and the eutectic, and the composition of the eutectic may be calculated from the intersection of the freezing-curves.

One interesting result is the conclusion that in the silicate magmas which have been the subject of experiment the minerals produced are all of very simple constitution; that, for example, olivine, diopside, akermanite, melilite, and anorthite have the simplest possible formulæ corresponding to their analyses and are not polymerised. Mineralogists will welcome this conclusion if it be true, for it has occasionally been the fashion on theoretical grounds to attribute a high degree of polymerisation to many minerals, and nothing is easier than to account for many difficulties if one may multiply the formula of a mineral by any number that is required. It should be added, however, that Doelter, calculating from his own experiments, is led to think that some of the minerals must have formulæ which are multiples of their empirical formulæ.

Vogt even goes a step further in his application of the principles of modern chemistry. The order of crystallisation appears to be by no means always that of the solubility, but indicates that a mineral is sometimes not so soluble as might be supposed. Now another principle in the modern physics of solutions is that by adding to a solution of one substance a new electrolyte containing an ion common to both the solubility of the first is diminished, and Vogt does not hesitate to apply this principle.

Thus spinel and felspar in mutual solution, when felspar is in large excess, should on cooling yield felspar first. But in many basic rocks spinel is the first to crystallise; this is, according to Vogt, due to the presence of ferromagnesian silicates containing the Mg-ion which is also present in spinel; if these be partially dissociated the solubility of the aluminate will be lowered.

An obvious criticism on this argument is that if the dissociation is so slight that it may be ignored for one purpose, it is hardly fair to invoke its powerful action for another, and it is possible that Vogt in his enthusiasm for a theory attempts to explain too much by its aid.

It is clear, however, that the labours of Vogt have been precisely in the direction indicated by Teall in the words that I have quoted, "experiment controlled by the modern theory of solution"; and if his opponents are tempted to think that he may have carried the principle too far with insufficient data, they cannot but admire the brilliancy, the persistency, and the ingenuity with which he has applied the newer theories of solution at every turn.

Heycock and Neville's Work on Alloys.

I must next refer briefly to another remarkable series of researches which have recently been published.

The laws which govern the solutions of metals in metals, that is to say alloys, appear to be the same as those which prevail in the case of other solutions; it is in alloys that the nature of eutectic mixtures has been most fully studied; and the phase-rule and Roozeboom's deductions from it have been applied with signal success to their investigation. A new impulse has been given to the subject by the work of Heycock and Neville which is summarised in their Bakerian lecture delivered last year upon the copper-tin series of alloys. They have studied the changes which occur during the cooling of an alloy by taking small ingots of the cooling metal and chilling them at certain temperatures; this arrests the gradual process of cooling and causes all that is liquid at the moment of chilling to become suddenly solid; it is then possible by polishing and etching the ingot to show the solid crystals set in the congealed ground-mass and to study their nature. They have been able to interpret their results by means of Roozeboom's remarkable work on the solidification of mixed crystals published in 1899. For our present purpose it is sufficient to consider these results as applied only to alloys. If a diagram be constructed with the temperatures for ordinates and constitution for abscissæ, Roozeboom has shown that two curves may be drawn. The first is the freezing-point curve, or *liquidus*, giving the temperatures at which an alloy of any composition begins to solidify: this is a broken curve and each section of it represents the temperature of equilibrium between the liquid and a different solid alloy; the breaks represent the temperatures and constitution of the liquid at which one solid ceases to be produced and another begins. The curve is, of course, far more complicated than the simple V of Meyerhoffer, since that represents the cooling of a mixture the constituents of which do not form compounds or isomorphous mixtures, whereas the alloys do both. In this respect the alloys resemble a silicate magma which is crystallising as a rock-mass; indeed it will be remembered that Mendeléeff insists upon the general similarity of silicon compounds to metallic alloys.

The second curve of Roozeboom is the melting-point curve, or *solidus*, representing the temperatures at which an alloy of given composition becomes completely solid. Points above the liquidus represent the condition of alloys which are completely liquid; points below the solidus that of alloys which are completely solid; points between the two that of cooling alloys which are only partially solid; and the curves themselves show which solid compounds can be in equilibrium with the liquid and with each other at any temperature.

The cooling-curves of Roberts-Austen and Stansfield had shown that considerable evolutions of heat may occur in cooling alloys far below the temperature of solidification, indicating that changes are going on in the solid as well as in the liquid condition. Heycock and Neville carry their investigations below the temperature of complete solidification and study these changes also.

In the case of the copper-tin series of alloys they find that, according to the temperature and constitution of the liquid, crystals belonging to no less than six different types may separate, namely:—

α, a solid solution of Cu with less than 9 per cent. of Sn.
β, a solid solution of Cu with less than 27 per cent. of Sn.
γ, of which the constitution is not known.
δ, which probably has the composition Cu_4Sn.
η, which probably has the composition Cu_3Sn.
H, which probably has the composition CuSn.

Both β and γ are unstable at ordinary temperatures. The compound δ crystallises out of β or γ while they are already in the solid state, when the temperature falls sufficiently.

A glance through the 101 photographs of chilled and etched ingots which accompany Heycock and Neville's paper on this series of alloys shows how impossible it would be from the final composition of the solid alloy to ascertain the various stages through which it has passed during cooling; as the authors remark, it is of the nature of a palimpsest. For example, the alloy, containing 14 atoms of tin to 86 of copper, consists at 800° of α crystals in a ground-mass which probably contains β; it solidifies at about 775°; at 675° there are only β crystals; at 600° there are α and β crystals, but here α has crystallised out of β after it became solid; at 530° there is a much larger proportion of α; at 470° there are α crystals immersed in a mixture of α and δ into which the residual β has broken up on cooling.

If the course of events is so complex in an alloy of only two metals, how much more difficult must it be to decipher in the case of a mass of complicated silicates which are even more prone to form isomorphous mixtures, such as we have in a solid rock, not to mention the additional presence of aluminates, oxides, and sulphides. And yet geologists are accustomed to speculate freely about the crystallisation of rock constituents from the magma without taking account of anything save the final stage.

I cannot help thinking that the experimental method of Heycock and Neville will have to be applied to the study of slags and fused silicates if we are to trace successfully the evolution of rock species. The value of their work to geologists is not only that the results are skilfully interpreted by the light of modern physical chemistry, but primarily that it is experimental work upon actual crystallising materials.

Supersaturated Solutions.

I do not myself see how we can do otherwise than apply to the study of rock-magmas all that can be learnt from physical chemists concerning the behaviour of solutions, for though we cannot attain in laboratory experiments the high temperatures and great pressures at which rocks may have crystallised, there is no reason to believe that these introduce more than a difference of degree. The principles of equilibrium between the various crystallising components probably remain the same, whatever may be the temperatures and pressures at which they have solidified.

It must at the same time be confessed that most of the experiments upon which the modern theory of solutions has been built up have been conducted upon dilute solutions, whereas the problems of crystalline growth are concerned, not with dilute nor even with saturated solutions, but only with solutions which are supersaturated. There is some force in the objection of Doelter that the results of such experiments may not be directly applicable to crystallising slags.

For example, as I have already mentioned, doubt has been expressed in the case of silicate magmas, whether the substances in solution are the minerals about to crystallise or only their constituents; whether viscosity and supersaturation may not invert the theoretical order of their appearance; whether we are to take into account possible dissociation of the molecules or not; whether the presence of a common ion in these minerals is a factor which determines their mutual solubility. In fact, very little is known about the actual condition of the materials in a strong solution, although I do not know that there is any evidence available which forbids us to regard a solution about to crystallise as a mixture of liquids one of which is about to pass into the solid state.

But if little is known about the nature of strong and supersaturated solutions, a good deal may be learnt about their behaviour. Having complained that we need experiments in this field, I may perhaps be pardoned if I allude to some unpublished experiments of my own which relate to the general behaviour of crystallising liquids, and appear to me to explain two difficult problems in petrography. To such experiments the objection of Doelter does not apply.

The Metastable and Labile Conditions.

When a solution of any salt such as alum or sodium nitrate is allowed to crystallise at a uniform temperature the crystals will only grow so long as the solution is supersaturated; a crystal growing in the supersaturated solution will continue to do so until a condition of equilibrium is attained. If the solution be kept at rest and maintained at a constant temperature, the crystal will continue to concentrate the liquid around itself and to withdraw solid material, until by diffusion of the impoverished liquid the whole mass is ultimately reduced to saturation, equilibrium is established, and the crystal ceases to grow; but most saturated solutions are so viscous that a very long time is required before this point is reached. Prolonged and vigorous stirring is required if the supersaturation is to be completely relieved within, say, a day; without stirring weeks may be required.

Further, it may be possible, as is well known, to keep a supersaturated solution in a sealed tube for years without change; and it is also possible to start crystallisation in such a liquid by dropping into it a crystal of the dissolved substance, or of one isomorphous with it, or sometimes by shaking it.

But it is, perhaps, not generally known that supersaturated solutions are of two sorts.

In 1897 Ostwald published some experiments upon supercooled liquids and supersaturated solutions, which were carried out with the object of showing how extraordinarily minute are the quantities of solid material capable of starting crystallisation in such liquids, but at the same time that they have a limit of size. He directed attention to the radical difference which probably exists between the state of a saturated solution which cannot crystallise spontaneously and that of the more strongly supersaturated solution which can do so.

The former is one in which crystallisation can either take place spontaneously or can be induced by stirring or shaking, or a variety of causes: this Ostwald calls the *labile* state. The latter is one in which crystallisation can only take place if a solid crystal of the dissolved substance, or a fragment of one, is brought into contact with the liquid: this he calls the *metastable* state. It is highly probable that no amount of stirring or shaking, or introduction of foreign substances, can make the metastable liquid crystallise.

Until recently no attempt to ascertain the exact limit between the metastable and labile states, or even to establish the existence of such a limit, had been successful, and practically no attention has been paid to the difference between them. Tamman, who measures the velocity of crystallisation by counting the number of the centres of growth or nuclei which appear in a supersaturated solution, does not recognise any distinction between the two states.

During the present year a number of experiments carried on by Miss F. Isaac and myself upon the strength of solutions from which crystals are growing have shown that it is easy to determine the changing concentration of a cooling solution by an optical method, to show that it passes into the labile state, and to ascertain the temperature at which the transition occurs. We have found, for example, that a solution containing 48 per cent. of $NaNO_3$ is saturated at 26°, is metastable between 26° and 16°, and crystallises spontaneously below that temperature; one containing 52 per cent. of $NaNO_3$ is saturated at 44°, and becomes labile at 35°.

In the metastable state inoculation by a solid germ of the dissolved substance, or of one isomorphous with it, is *necessary* in order to cause the liquid to crystallise; in the labile condition solid germs may be spontaneously generated from the liquid. Take, for example, a test tube filled with a solution of sodium-nitrate containing 48 parts of the salt in 100 parts of solution, which is metastable at ordinary temperatures; if crystals make their appearance in this solution it will only be because the dust of the room contains minute particles of sodium-nitrate which fall into the tube, or because crystals are deposited where drops have evaporated near the surface, and accordingly the first crystals appear at the surface of the liquid, and grow there until they are large enough to fall to the bottom. I find that such a solution, if enclosed in a sealed tube so as to prevent access of germs and evaporation, cannot be made to crystallise above the temperature of 16°, although it is supersaturated at all temperatures below 26°.

Again, let a hot solution of the same strength containing 48 per cent. of the salt be allowed to cool down while being stirred. If dust containing $NaNO_3$ can be excluded, the liquid will not crystallise until the temperature falls to 16°, when the solution passes from the metastable to the labile condition. A cloud of nuclei will then form throughout the liquid, and each will proceed to grow as a separate crystal; the immediate effect is to reduce the liquid to the metastable state so that no more crystals are produced, but each of these continues to grow from the liquid with which it is in contact.

If dust be not excluded, crystals may make their appearance upon the surface of the liquid and will soon sink; but even though they be stirred about actively in the solution the liquid as a whole remains in the metastable state until a temperature somewhat below 16° is reached, when the labile region is entered and a cloud of new crystals makes its appearance.

It follows, therefore, that in a cooling supersaturated solution, from which germs have not been excluded, there are normally two periods of growth: one in which a comparatively small number of isolated crystals are growing regularly, and a subsequent period in which a shower of small crystals is produced. Only if the rate of cooling be sufficiently slow, or the stirring be sufficiently violent, to keep the liquid in the metastable condition will there be no second period, no sudden precipitation of nuclei.

These events take place in all the aqueous solutions which I have examined, and I am surprised that they have not been discovered before. They afford a possible explanation of two common features of igneous rocks, and of slags—namely, the growth of comparatively large and isolated porphyritic crystals, or phenocrysts, and the appearance of the same mineral at two or more different periods. The origin and the arrested growth of phenocrysts have generally been attributed to sudden change of temperature, of pressure, or of hydration, and no other plausible explanation has been given, although, as has been sometimes pointed out, they may occur in batholites where there is no independent evidence of such changes. Pirsson has recognised the utter impossibility of the ordinary theory and has recently suggested that each mineral has its crystallisation interval during which it continues to grow, and that this is terminated by the increasing viscosity of the magma, which checks the supply of further material to the growing phenocrysts and establishes new centres of crystallisation. A similar explanation was adopted by Crosby for the quartz-porphyry of the Blue Hills. He expresses it by saying that owing to the increased viscosity the rate of cooling overtaxes the molecular flow, which cannot keep pace with the crystallisation. It is so difficult to find any satisfactory theory for the growth of phenocrysts that they have even been attributed to the effect of earthquake shocks.

Now in a silicate magma, in all probability, the temperature is sufficiently high to be that of the metastable condition, the rate of cooling sufficiently slow to keep the liquid in that condition for a considerable time, and the viscosity sufficiently great to prevent the growing crystals from sinking at once; we have, therefore, all the conditions favourable for the growth of *porphyritic* crystals; these must have generally originated throughout the liquid as spontaneous nuclei if the magma entered the labile state, or may have been started by inoculation or cooling at the margin if the magma as a whole remained in the metastable state. In the latter case suppose that further somewhat sudden cooling brings the magma to the labile condition, then there will be a sudden and spontaneous second growth of nuclei which will not be able to attain the dimensions of the porphyritic crystals; we have here all the conditions necessary for a *second generation* of one of the constituents of the rock.

It is not necessary, therefore, to suppose that changes of pressure played any very great part in these matters. I believe it will be found that considerations of temperature and solubility are far more important. Similarly in the case of the salt deposits van 't Hoff came to the conclusion that practically the only effect of changes of pressure is to displace the temperature of formation of the various compounds and not to alter their order or their nature; he estimates that this displacement is comparable with that of the melting points under the same agency, and in the case of the calcium-magnesium chlorides only amounts to a few thousandths of a degree for one atmosphere of pressure.

Perhaps when we can ascertain the temperature at which silicate magmas pass from the metastable to the labile condition we may use this knowledge to determine the exact temperature at which certain of their minerals crystallised.

Ordinary petrographical descriptions supply numerous examples of the difference between the metastable and labile conditions to anyone who will read them in the light of the suggestion which I have made; others are to be found in such experiments as those of Vogt or Doelter.

My own hope is that when more experiments have been made upon mixed *supersaturated* solutions it will be found that most, if not all, of the features of rock development are paralleled by the ordinary processes of crystallisation, but that motion, supersaturation, and supercooling are most important factors.

The very similarity between the differentiation of the alumo-alkaline and ferro-magnesian minerals on a small scale in the rock, and that of the alumo-alkaline (or salic) and ferro-magnesian (or femic) rocks themselves on a large scale, points to some similarity of origin.

In order to avoid burdening this Address with detail I have merely chosen the researches of van 't Hoff, Vogt, Doelter, and Heycock and Neville as illustrations of experimental work conducted on the lines of modern physical chemistry, and have omitted much that might have been mentioned; the valuable researches of Pelouze, Lagorio, Morozewicz, and Loevinson-Lessing, and the melting-point determinations of Joly I have not quoted, because they belong for the most part to an earlier period than that which I am considering, and have been discussed by Teall and other writers.

Many very interesting speculations I have passed over entirely, because my object has been to focus attention upon experimental evidence. I cannot help thinking that these speculations are often based upon chemical actions and equilibria that may be impossible; but we cannot criticise them for lack of evidence, and I return to my original statement that geology is only beginning to enter the experimental stage.

An earnest beginning is, however, being made. The researches on mineral and rock synthesis which I have already quoted are laying a solid foundation; and I see no reason why something of the sort which has been done by van 't Hoff and his collaborators for the aqueous deposits of Stassfurt should not ultimately be worked out for an igneous complex, though it may involve tenfold the labour and tenfold the time. We have already to welcome the establishment by the United States Geological Survey of a laboratory for the express purpose of applying to minerals and rocks the exact methods of modern physics and physical chemistry. The very suggestive research of Day and Allen upon the thermal properties of the felspars is a promise of the sort of work that may be expected from such laboratories.

I fear it will be only too evident to those who have given me their patience during this Address that I approach the problems considered in it from the point of view, not of the geologist or the chemist, but of the crystallographer, to whom the birth and growth of crystals are a study in themselves. Whether we watch with the microscope a tiny crystal growing from a drop of solution, or contemplate with the imagination the stages by which the fiery lavas of past geological periods sank to rest and crystallised, we view the same process; it is the transformation of liquid into crystal. Not necessarily into a solid, for recent research shows that there is no dividing line between liquid and solid; a plastic solid body may flow; a solid glass is only a supercooled liquid; witness, for example, the experiments of Adams on rocks, and of Tamman on supercooled liquids. The real primary distinction is between crystalline and non-crystalline material, and there is even good reason to believe that some crystals are liquid without ceasing to be crystals.

The properties of most rocks, of metals, alloys, ice, and many other substances are due to the fact that they consist of crystals, and the importance of the study of the latter is now, I trust, being brought home alike to chemists, physicists, geologists, and engineers in connection with problems relating to the strength, the movements, the origin and changes of what are usually called solids.

And so I close, as befits a student and teacher of crystallography, with the hope that renewed attention may be paid to this subject, and that it may attract the interest of many a keen intellect in South Africa. The higher scientific studies are now establishing themselves as an integral part of the educational and intellectual life of the country: this is in no small measure due to the South African Association; and we may hope that the visit of the British Association will be of some help to her younger sister in the task of diffusing a taste and an interest for the pure truths of science and the studies that they both hold dear.

SECTION D.

ZOOLOGY.

OPENING ADDRESS BY G. A. BOULENGER, F.R.S., V.P.Z.S., PRESIDENT OF THE SECTION.[1]

The Distribution of African Fresh-water Fishes.

I THINK I may ascribe the honour of having been chosen to preside over this Section to the fact that I have specially applied myself to the study of a large class of the animals of the part of the world in which we are for the first time assembled. The subject of the Address which it is the custom to deliver on such an occasion was therefore not difficult to choose—a general survey of the African fresh-water fishes from the point of view of their distribution.

It has repeatedly been pointed out that no division of the world can answer for all groups of animals, differences due to the period at which they appeared and to their ability or inability to spread over obstacles, whether of land or water, precluding any attempt to make their present distribution fit into the frames of the general zoogeographer. The great divisions of the earth, as outlined by our eminent Vice-President, Dr. Sclater, nearly half a century ago, and based mainly on a study of passerine birds, have therefore varied considerably according to the standpoint of the many workers who have followed in his footsteps. Fresh-water bony fishes particularly lend themselves to a uniform treatment, their principal groups having sprung up, so far as palæontological data teach us, about the same period in the history of the earth, and branched off in many directions within a geologically speaking brief lapse of time, most of them, besides, being regulated in their distribution by the water-systems. How greatly their distribution differs from that of terrestrial animals has long ago been emphasised. Thus, latitudinal range, so striking in many African reptiles, does not exist in fishes: the key to their mode of dispersal is, with few exceptions, to be found in the hydrography of the continent; and, as first shown by Dr. Sauvage, latitude and climate, excepting of course very great altitudes, are inconsiderable factors, the fish-fauna of a country deriving its character from the head waters of the river-system which flows through it. In this way, for instance, the Lower Nile is inhabited by fishes bearing a close resemblance to, or even specifically identical with, those of Tropical Africa, and strikingly contrasting in character with the land-fauna on its banks. Such being the case, it seems at first as if the geographical divisions of the fish-fauna were a matter of extreme simplicity, and that a knowledge of the river-systems ought to suffice for tracing areas which shall express the state of things. But we must bear in mind the movements which have taken place on the surface of the earth, and owing to which the conditions we find at present may not have existed within comparatively recent times; and this is where the systematic study of the aquatic animals affords scope for conclusions having a direct bearing on the physical geography of the near past. To mention two examples, the fishes of the Nile show so many specific types in common with those of the Senegal-Niger, now more or less completely separated by the Chad basin, that we felt justified in postulating a recent communication between these water-systems, which has been fully confirmed by the study of the Lake Chad fishes; whilst, on the other hand, the greater difference between the fishes of the Nile and those of the Congo basin, the waters of which interlock at present in such a way that it is believed possible, at certain seasons, for a man in a boat to pass from the one into the other, points to the existence, until very recently, of a more effective separation. Such problems are of the greatest interest, and a more exact knowledge of the fishes will help towards their solution.

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[1] Slightly abridged.

There is another aspect of the question of geographical distribution which has assumed special importance of late, especially in the writings of Prof. Osborn, Mr. Lydekker, and Dr. Scharff, and of which Dr. A. E. Ortmann's paper on the distribution of Decapod Crustaceans, published three years ago, may be taken as an example. One of the conclusions formulated therein is that "any division of the earth's surface into zoo-geographical regions which starts exclusively from the present distribution of animals without considering its origin must be unsatisfactory." But in certain groups of animals, possibly in most, the question of their origin is not easily settled; in the case of the African fresh-water fishes, for instance, we sadly lack all direct palæontological data, such as have sprung up lately in marvellous profusion in the case of the mammals, and notwithstanding the great progress in our knowledge of the changes that have taken place in the configuration of the world in Secondary and Tertiary times, which has been conveyed to a wide circle of readers chiefly through the luminous works of Neumayr, Suess, and de Lapparent, there is still much that is open to discussion. It must be admitted—and it is well to draw special attention to this point—that Dr. Ortmann's maps of the land-areas in past periods, which render his suggestive paper so attractive, cannot be accepted as the expression of well-established geological facts, and are, in some respects, gravely misleading. If I have attempted to deal with this subject on the lines laid down by Dr. Ortmann, whilst realising the want of many necessary data, palæontological and geological, on which to base conclusions, it is with a due sense of humility, being fully aware that the suggestions now offered must be regarded as mere speculations.

The time has come for a stock-taking of our immensely increased material, the previous accounts of the distribution of African fishes given by Dambeck in 1879, by Günther and by Sauvage in 1880, and by Palacky in 1895, no longer answering, even approximately, to our present knowledge, as may be seen by comparing the lists given by these authors with the one I have quite recently published in the *Annals and Magazine of Natural History* as a basis for the sketch here attempted.

How little we knew of the fresh-water fishes of Africa when the subject was dealt with by the above-named authors is exemplified by the enormous number of genera and species which have been discovered within the last few years, thanks chiefly to the enlightened activity of the Governments of Egypt and the Congo Free State, and to the initiative of Prof. Ray Lankester in organising explorations of the great lakes of Central Africa. The waters of the French Congo and Cameroon, the Niger, Abyssinia, and the interior of East Africa, have also yielded a large number of novelties; even the Nile, comparatively so well known, has been productive of many and remarkable additions to our knowledge. The importance of a better acquaintance with the fishes of the Lower Nile, a district believed to have been particularly well explored, can be measured by comparing the present data with those to which Prof. Gregory, on the faith of Dr. Günther's list, appealed to justify his theory of a direct connection in the past of the Upper Nile with the Jordan through a river flowing along what is now the Red Sea. To this question we shall revert presently.

Whilst the exploration of rivers and lakes has resulted in such a rich harvest, it remains a matter for serious regret that we should still be without any information as to the precursors of the African fishes. In spite of diligent search over a considerable portion of the great continent, no remains of any post-Triassic fishes have yet been discovered in Tropical and South Africa, and our acquaintance with Tertiary Teleosts generally is still almost as scanty and fragmentary as it was twenty years ago, although much has been done by Dr. Smith Woodward in elucidating the affinities of such remains as have been exhumed. In the circumstances we have to fall back on our imagination to explain the origin of the most important groups characteristic of the present African fish-fauna, and much hazardous speculation has been indulged in. Thus, without any sort of evidence, the Cichlid Perches of Africa have been supposed to emanate from ancestors inhabiting hypothetical Jurassic or Cretaceous seas extending over Central Africa, whilst connecting land areas have been too freely postulated to account for the resemblance between the fishes of Africa and Tropical America, and antarctic continents devised to explain the presence of Galaxias in South Africa. To these suggestions I shall refer further on when dealing with the distribution of the families to which they were intended to apply. Although it is highly desirable that zoologists should base their theories of geographical distribution upon geological data, I think we must regret the growing tendency to appeal to former extensions of land or sea without sufficient evidence, or even contrary to evidence, in order to explain away the riddles that offer themselves.

Twenty-five years ago a list of the African fresh-water fishes would have included the names of about 350 species (Günther gave the number as 255 only), some fifty of which have since lapsed into the synonymy, whilst at the present day we are acquainted with 976 species, referable to 185 genera and forty-three families. Of the latter five were then unknown, or unknown to have representatives in this part of the world. The forty-three families are here enumerated, with an indication of the number of genera and species according to the most recent census:—

CHONDROPTERYGII.

PLAGIOSTOMI.

1. Carchariidæ, 1, 1.
2. Pristidæ, 1, 1.

CROSSOPTERYGII.

CLADISTIA.

3. Polypteridæ, 2, 11.

DIPNEUSTI.

4. Lepidosirenidæ, 1, 3.

TELEOSTEI.

MALACOPTERYGII.

5. Elopidæ, 2, 3.
6. Mormyridæ, 11, 108.
7. Notopteridæ, 2, 2.
8. Osteoglossidæ, 1, 1.
9. Pantodontidæ, 1, 1.
10. Phractolæmidæ, 1, 1.
11. Clupeidæ, 6, 7.
12. Salmonidæ, 1, 1.
13. Cromeriidæ, 1, 1.

OSTARIOPHYSI.

14. Characinidæ, 20, 93.
15. Cyprinidæ, 12, 202.
16. Siluridæ, 37, 187.

APODES.

17. Anguillidæ, 1, 6.

HAPLOMI.

18. Galaxiidæ, 1, 2.
19. Kneriidæ, 1, 2.
20. Cyprinodontidæ, 5, 39.

CATOSTEOMI.

21. Gastrosteidæ, 1, 1.
22. Syngnathidæ, 2, 3.

PERCESOCES.

23. Scombresocidæ, 1, 1.
24. Atherinidæ, 2, 3.
25. Mugilidæ, 2, 13.
26. Polynemidæ, 3, 3.
27. Sphyrænidæ, 1, 1.
28. Ophiocephalidæ, 1, 3.
29. Anabantidæ, 1, 14.

ACANTHOPTERYGII.

30. Centrarchidæ, 1, 3.
31. Nandidæ, 1, 1.
32. Serranidæ, 6, 8.
33. Sciænidæ, 1, 1.
34. Pristipomatidæ, 2, 2.
35. Sparidæ, 1, 1.
36. Scorpididæ, 1, 3.
37. Osphromenidæ, 1, 1.
38. Cichlidæ, 30, 179.
39. Pleuronectidæ, 2, 2.
40. Gobiidæ, 2, 31.
41. Blenniidæ, 3, 3.

OPISTHOMI.

42. Mastacembelidæ, 1, 23.

PLECTOGNATHI.

43. Tetrodontidæ, 1, 4.

In discussing the distribution of the fresh-water fishes it is necessary to divide them into four principal categories:—

(1) Those living part of the year in the sea. This category is again subdivided into anadromous forms, breeding in fresh water (ex. some Clupea), and catadromous forms, breeding in salt water (ex. Anguilla).

(2) Those living normally in the sea, but of which certain colonies have become land-locked, or have separated themselves from the marine stock still represented on the neighbouring coast (ex. some Gobiidæ and Blenniidæ).

(3) Those which, although entirely confined to fresh waters, have as nearest allies species living in the sea, and which there is reason to regard as more or less recently derived from marine forms (ex. Galaxiidæ, Tetrodontidæ).

(4) Those belonging to families entirely (ex. Mormyridæ, Characinidæ) or chiefly (ex. Siluridæ, Cyprinodontidæ) restricted to fresh waters.

The forms of the first and second categories may be entirely neglected in dealing with the distribution of fresh-water fishes. Their range is regulated by the sea, and they must be dealt with in conjunction with littoral forms. Eighty-six species in the list of African fresh-water fishes belong to these categories.

The third category is of secondary interest in the history of the fresh-water fauna; but, as in the case of Galaxias, forms referred to it may give rise to discussion.

It is with the members of the fourth category that we shall mainly deal in the portion of this Address which is devoted to the origin and mode of dispersal of the African fishes.

THE POLYPTERIDÆ.—This is incontestably the most remarkable family of African fishes. Entirely restricted to Tropical Africa and the Nile, without any known near allies, living or extinct, its history is one of the greatest riddles in ichthyology. From the evolutionary point of view, no group is of greater interest, owing to its probable relation to the Chondropterygians or Elasmobranchs, to the Osteolepid Crossopterygians, out of which the Lung-fishes seem to have been evolved, and to the earliest pentadactyle vertebrates, the Stegocephalous Batrachians. Although generally brigaded by modern systematists with the Osteolepida in the order Crossopterygii, it is still doubtful whether it should not rank as a distinct order, Cladistia of Cope, the characters which differentiate it from these early Teleostomes being perhaps of greater importance than those which separate these from the Dipneusti. Until we have some proof to the contrary, we are justified in regarding the Polypteridæ as having arisen in Africa from fresh-water ancestors, themselves derived from early Mesozoic types which are entirely hypothetical.

THE LEPIDOSIRENIDÆ.—Protopterus in Africa and Lepidosiren in South America are specialised modifications of the Ceratodontidæ, still represented by one species in Australia, which have left remains in Triassic, Rhætic, Jurassic, and Cretaceous rocks of Europe, North America, Patagonia, North and South Africa, India, and Australia. The distribution of the Ceratodontidæ has therefore been, at different periods at least, a world-wide one, and we should feel justified in assuming the living representatives of the Lepidosirenidæ to have been evolved out of this family independently in Africa and in South America. On the other hand, in view of the old age of the group, there is no reason why the Lepidosirenidæ should not have passed from one of the present continents into the other when they were connected by land. As Protopterus is a less specialised type than Lepidosiren, the probabilities would then be that the former originated in Africa. Mr. Lydekker, in his "Geographical History of Mammals," states his opinion that Lepidosiren reached its present habitat by way of Africa. The mode of life of these fishes renders them less dependent on hydrographical systems, and the distribution of the species, which cannot yet be traced in a satisfactory manner, is evidently very different from that of other groups.

THE MORMYRIDÆ.—This extraordinary group, of which so many new and remarkable types have been discovered within the last few years, especially in the Congo, is peculiar to the fresh waters of Tropical Africa and the Nile. Its morphology shows it to be highly specialised from some very lowly Teleostean ancestor. This I believed to be found in the Albulidæ, a family already represented in Cretaceous seas, and of which one species still occurs on the West Coast of Africa. But Dr. Ridewood, who has recently made a much more careful study of the cranial characters of the two families, is unable to support the suggestion of a direct descent from the Albulidæ. It nevertheless remains probable that the Mormyridæ were derived from forms more closely allied to the known Albulidæ than to any other family with which we are acquainted, and which no doubt lived in Cretaceous seas; and we may therefore assume that the Mormyridæ originated in Africa, and were evolved out of Cretaceous marine ancestors.

THE NOTOPTERIDÆ.—This is another eccentric family, having many points in common with the Mormyridæ and with the North American Hyodontidæ. It is represented by five species, three of which live in the Indo-Malay region and two in Tropical Africa. Its derivation is still a mystery. The fact that its most specialised form (Xenomystus) is African, and that a species differing but little from the living Notopterus occurs in fresh-water deposits in Sumatra, which are regarded by some geologists as of Middle Eocene age—although, as stated further on *à propos* of the Cyprinidæ, there is reason for regarding them as Miocene, or even later—justifies us in believing, until further palæontological evidence be available, that the African forms are immigrants from the East.

THE OSTEOGLOSSIDÆ.—An archaic type of Teleosteans, now represented by two genera in South America, by one in Australia and the Malay Archipelago, and by a fourth in Tropical Africa and the Nile. Excellently preserved fossils from the Middle Eocene of Wyoming (Dapedoglossus) are most nearly allied to, but more generalised than, the Australian-Malay genus; whilst the less satisfactorily known British Lower Eocene Brychætus appears nearer to the South American Arapaima. The African genus Heterotis is the most specialised form. The Osteoglossidæ are evidently an ancient group, now in process of extinction, which once had a very wide distribution. The fact of the only known fossil representatives being from North America and Europe does not seem sufficient evidence of the northern origin of the family, as suggested by Mr. Lydekker.

PANTODONTIDÆ, PHRACTOLÆMIDÆ, CROMERIIDÆ.—Three monotypic families peculiar to Africa. The first bears a near relationship to the Osteoglossidæ, and was probably derived from them; but the two others, discovered within the last few years, are so aberrant and isolated among the Malacopterygians that we are absolutely in the dark as to their possible origin.

THE CHARACINIDÆ.—This is one of the larger groups of African fishes—with ninety-three species, referred to twenty genera, mostly from the Nile and Tropical Africa, as far east as the great lakes, but only very sparsely represented in East and South Africa.

One of the most striking features of the South American fresh-water fish-fauna is the extraordinary number and variety of forms of the Characinidæ, unquestionably one of the most lowly and generalised groups of exclusively fresh-water Teleosts. There occur in that part of the world as many as 500 species (about two-fifths of the whole fresh-water fish-fauna), divided among some sixty genera. The carnivorous forms predominate, but the herbivorous or semi-herbivorous are also very numerous. The latter would evidently compete with the Cyprinids, their near but more specialised relatives, which are so numerously represented in North America; and it is a remarkable fact that not a single Cyprinid is known to extend further south than Guatemala.

Although palæontology has taught us nothing respecting the Characinids, we have reason to assume, from the morphological point of view, that they were the precursors of the Cyprinids, which, we know, were already abundantly represented in North America and Europe in Lower Tertiary times, when the Isthmus of Panama was under the sea. When, in the Miocene, North and South America became re-united, the waters of the latter part of the world must have been already so fully stocked with Characinids as to prevent the southern spread of the Cyprinids. This is the only explanation that can be offered of the total absence of Cyprinids in South America, considerations of climate being of no avail in view of their distribution all over Africa. If, therefore, the Characinids existed in profusion in South America before the Miocene period, we are justified in claiming for them a high antiquity, and by putting it at the Upper Cretaceous we need not fear going too far back.

THE CYPRINIDÆ.—These fishes, as mentioned above, are very closely related to the preceding, and there is every reason to believe the former to be derived from the latter. Their least specialised genera (Catostominæ) are now found in North and Central America (about sixty species), whilst three species, referable to the same genera, inhabit Eastern Siberia and China. These Catostominæ are known to have had representatives in the Eocene of North America, whilst the more specialised Cyprininæ, which constitute the great bulk of the family both in the new world and in the old, have left remains in the Oligocene and later beds in North America and Europe. It is, therefore, highly probable that the Cyprinids originated as a northern offshoot of the South and Central American Characinids, and thence spread to Eastern Asia, at least as early as the Upper Eocene. By the time (Miocene) they had reached India, where they now form the great majority of the fresh-water fishes, Africa had been connected with it by a wide belt of land, and no obstacle prevented their western extension. This comparatively recent migration accounts for the practical identity of the genera and the often very close affinity of the species of the Cyprinids of India and Africa. At the same period the land-area connecting India and Africa with Madagascar had disappeared, and the Cyprinids never reached that great island, where no doubt they would have thriven, if we judge by the results of the introduction by man of the gold fish, said to be in process of strongly reducing the numbers of the native Malagasy fresh-water fishes with which it is in a position to compete. Competition is always an important factor in the distribution of a group of animals, and the confinement of the Characinids to the waters of the western and central parts of Africa at the time of the immigration of the Cyprinids from the east must be the explanation of the comparative abundance of the latter and the scarcity of the former in those parts of the continent east of the Rift Valley which are not drained by rivers flowing from the central parts. The Cyprinids must have spread more rapidly than the Characinids, and being also less partial to heat they have thriven in the waters of South Africa, where at present only two species of Characinids—both carnivorous forms—are known to extend south of the Zambesi system. Of the 202 species recorded from Africa thirteen are found in North-West Africa, sixty-three in East Africa (exclusive of the Zambesi), and twenty-one in South Africa.

THE SILURIDÆ.—This large family is almost cosmopolitan in tropical and warm regions; and although the great bulk of the species are restricted to fresh waters, a certain number (chiefly of the sub-family Ariinæ) occur on the coasts and in the estuaries. Morphologically these fishes are so closely allied to the Characinidæ and Cyprinidæ that we must assume them to have been evolved from a common ancestral stock, probably in Cretaceous times; but connecting forms such as we should expect to find in deposits of that age are still unknown. The Silurids appear in the Lower Eocene estuarine beds of England and France, as forms closely related to the living Ariinæ and Bagrinæ, and further allied forms follow in the Middle Eocene of various parts of Europe and North America. In the Upper Eocene of Lower Egypt estuarine deposits contain well-preserved remains of forms which appear to be only specifically separable from the Bagrus still living in the Nile. The general distribution of these fishes was, therefore, in early Tertiary times very much the same as it is at present, and palæontology offers us no clue as to where they originated.

The exclusively fresh-water Silurids now found in Africa are all generically distinct from the South American forms, whilst the West African species that enter the sea belong to the same genus (Arius). The two exclusively fresh-water Silurids found in Madagascar show closer affinity with the African than with the Indian forms, and may have immigrated from Africa in the early Tertiary times through the bridge which then existed, unless they have been derived from marine types, which is quite possible.

THE GALAXIIDÆ.—Two small fishes originally described by F. de Castelnau as Loaches, and now referred to Galaxias, occur on the flats near Cape Town and in the Lorenz River, some twelve miles from its mouth in False Bay. They are of special interest as belonging to a family and genus long believed to be exclusively confined to fresh waters and characteristic of the extreme south of America, New Zealand, and Southern Australia. After Dr. Steindachner had first recognised the true affinities of the Cape species, Prof. Max Weber was inclined to regard this interesting discovery as affording a new argument in favour of the past antarctic continent on which so much has been written. But Dr. Wallace was nearer the truth when he suggested that a land connection within the period of existence of one species of fish, viz. *Galaxias attenuatus,* known from Chili, Patagonia, Tierra del Fuego, the Falkland Islands, New Zealand, and Southern Australia, would have led to much more numerous and important cases of similarity of natural productions than we actually find, and that we must rather look to the transport of the ova across the southern sea to explain this very remarkable distribution. A better acquaintance with the Galaxias has confirmed Dr. Wallace's supposition, as it is now an established fact that some species live in the sea.

As the early Tertiary "Antarctica," as designed by Prof. H. F. Osborn, does not involve South Africa, the presence of species of Galaxias at the Cape cannot, even on that hypothesis of continental extension, be explained except on the assumption of their marine origin.

THE KNERIIDÆ.—A monotypic family with two species, one from Angola, the other from East Africa. These little fishes are related to the Pikes, Esocidæ; and there is no reason that I can see against their being possibly derived from them, in which case they would be of northern origin, the Esocidæ, now confined to the northern hemisphere, being known from fresh-water deposits in Europe as far back as the Oligocene.

THE CYPRINODONTIDÆ.—The members of this large family are mostly Central and South American. They are comparatively few in Africa, but have representatives in every part, and also in Madagascar and the other islands of the Indian Ocean. Although principally restricted to fresh waters, not a few species are known to live in brackish water, whilst examples are known of their occurring far out at sea.

THE OPHIOCEPHALIDÆ AND ANABANTIDÆ.—Unknown fossil, and now restricted to Africa and South-Eastern Asia, we have no means of telling in what part of the world these two closely allied families originated. The Anabantidæ are more numerous in species, and these are of a more generalised type, in Africa than in Asia.

THE NANDIDÆ.—The recent discovery of Polycentropsis in the Lower Niger has added a genus to a small family previously known to be represented by three genera in South-Eastern Asia and by two in the northern parts of South America. The latter are more nearly related to the African genus than the former. Too little is known of the habits of these fishes to decide whether the hypothesis of a migration across the Atlantic, in the days when a shallow area with a string of islands connected the old world and the new, answers for their distribution. Their systematic position—specialised Perciformes—is against the assumption of their having existed in Cretaceous or early Eocene times. No fossil forms are known.

THE OSPHROMENIDÆ.—The only African representative, the genus Micracanthus, with a single species in the Ogowé, is hardly separable from the genus Betta, which, with six other genera, is characteristic of the Indo-Malay region and China. Palæontology gives no information on the earlier distribution of these highly specialised fishes. That a type so well organised for adapting itself to all sorts of waters, and so ready to acclimatise itself in any part of the tropical or subtropical countries where it has been transported by man, should have so restricted a range seems remarkable. Were it not for the existence of this African form, far away from the other members of the family, one might have felt inclined to look upon the Osphromenidæ as a very recent group, which has not had time to spread far from its original centre in South-Western Asia.

THE CICHLIDÆ.—As regards the number of species (179) this family ranks next to the Cyprinidæ (202) and the Siluridæ (187) in the African fresh-water fish-fauna, and, like these, it has representatives nearly all over the great continent. Although Cichlids may thrive in inland waters of considerable salinity, they are not known to have ever been found in the sea, even near the mouths of rivers. The facility with which they establish themselves in isolated waters, often untenanted by other fishes, such as wells in the Sahara, salt-water pools in the interior of East Africa, &c., has long been known, but by what agency this has been effected remains unexplained. Quite recently Dr. Lonnberg has reported on the exploration of a small isolated lake of volcanic origin on the Cameroon mountain, a lake 200 feet above sea-level, without any outlet, and situated about twelve miles from the nearest river and twice as far from the sea-shore. This lake was found to have a fish-fauna consisting exclusively of Cichlids, belonging to three genera and five species, two of which have been described as new.

The great bulk of the family inhabits Africa, including Madagascar, and America, from Texas to Montevideo; the number of generic types is greater, although the species are only slightly in excess, in the former than in the latter part of the world. Seven species inhabit Syria, three of these being also found in the Nile, and three are known from India and Ceylon. The American and Indian genera are all distinct from the African. A great number of species (fifty-five), all but one endemic, inhabit Lake Tanganyika, of which they form a little more than two-thirds of the fish-fauna; and many of these species belong to distinct genera, showing specialisation to a remarkable degree. Out of thirty recognised genera of African Cichlids, as many as fifteen are believed to be peculiar to Tanganyika. Lake Nyassa, with the Upper Shire, possesses also some remarkable endemic genera; but they are only four in number, and the number of species recorded up to the present does not exceed twenty-two. The rest of the species are mostly from West Africa and the Congo basin; but a few, referable to the two most widely spread genera, are found in East and South Africa. Madagascar has only four species, two belonging to an endemic genus, whilst each of the two others is referred to a widely distributed African and Syrian genus.

No fossils are known that agree closely with any of the recent genera, but a type of Perciforms, described by Cope as Priscacara, from Middle Eocene fresh-water beds in North America, presents all the characters which we should expect to find in the direct ancestors of the modern Cichlids, differing from the living forms in the presence of vomerine teeth, a serrated præ-operculum, and apparently eight branchiostegal rays. It has twenty-four vertebræ, a number lower than is found in most of the recent genera; and this indication is of importance for reasons that must be explained somewhat fully.

The lower Teleosteans (Malacopterygii and Ostariophysi, often united under the term "Physostomi") mostly have a high number of vertebræ; but when we pass on to the higher Acanthopterygii, we find very frequently, among most diverse families, the number reduced to twenty-four. That this number should occur with such frequency has struck many ichthyologists since Dr. Günther first directed attention to it, more than forty years ago, pointing out at the same time that in the Labridæ this number is almost constant in the tropical genera, whilst those genera which are chiefly confined to the temperate seas of the northern and southern hemispheres have an increased number. It has since been shown by Dr. Gill and by Prof. Jordan that this generalisation holds true of several other families of Acanthopterygians, and the latter authority, when discussing the subject at some length, came to the opinion that the state of things could be explained, from an evolutionary point of view, on the assumption that competition among various marine fishes being greater within the tropics has resulted in greater specialisation, by which the originally high number of vertebræ has been reduced. It is difficult, however, on this assumption to account for the fact that in so many cases the reduction should have resulted in the number twenty-four—neither one more nor one less—and this repeated in many families belonging to the same sub-order but otherwise only remotely related to one another. Three years ago, when dealing with the affinities of the flat-fishes, Pleuronectidæ, I was struck by the discovery that, in the unquestionably least specialised genus, Psettodes, the vertebræ are twenty-four in number, the other known genera having from twenty-eight to sixty-five, and that the numbers increased along the most probable lines of evolution. A consideration of other families, and of the fossil forms in which the number of vertebræ has been ascertained, soon convinced me that this rule also applies to them, and that the order of evolution had in every case to be reversed from that assumed by Prof. Jordan, whose interpretation I had previously accepted as correct. As a result of my investigation into this question I believe that the frequent occurrence of twenty-four vertebræ is due to the original Acanthopterygians having presented this number, that it has been retained in the more generalised members of the families which have branched off from them, and increased or, more seldom, reduced in the course of evolution.

The view which I entertained when first studying the Cichlids of Lake Tanganyika must be abandoned, and the direction of the supposed lines of evolution reversed, together with the signification given by me to the characters of increased number of dorsal and anal rays, or of multiple lateral lines which go more or less hand in hand with the increase in the vertebral segments. I must therefore repudiate the statement, first made by me in describing some of the new genera discovered by Mr. Moore in Lake Tanganyika, that they show features of generalisation, the contrary being the case. This has been shown by Dr. J. Pellegrin, who has recently published a monograph of the whole family Cichlidæ, in which he has very ably dealt with the question of the interrelation of the various genera from the phylogenetic point of view.

Two theories have lately been put forward as to the origin of the African Cichlids.

According to Mr. Moore, to whom we owe the discovery of so many new forms in Lake Tanganyika, the Cichlids are of marine origin, and penetrated into a hypothetical Central African sea in præ-Tertiary times. But as no Perciform fish of any sort is known earlier than the Upper Cretaceous, and no Perch, in the widest sense, before the Lower Eocene (Prolates), the possible existence at that remote time of so specialised a type of Perches as the Cichlids is absolutely contrary to palæontological evidence. Further, such an explanation is unsupported by any geological data, no trace of Jurassic or Cretaceous deposits having been found on the plateau of Central Africa, notwithstanding much search over a considerable portion of the Congo State. It is impossible to imagine that such a sea could have existed without leaving any sedimentary deposits whilst its relics were being preserved in Lake Tanganyika. Besides, the distinguished Belgian geologist, Prof. J. Cornet, who has paid special attention to this question, and has himself surveyed a considerable part of the territory of the Congo State, regards the Tanganyika as by no means a very ancient lake, its formation not dating back beyond Miocene times. I may also here point out that Mr. Moore's interpretation of the affinities of the so-called "halolimnic" Mollusca has not received any support from those best able to judge of its merits. Mr. E. A. Smith, from the recent conchological, and Mr. Huddleston, from the palæontological point of view, have recently discussed his conclusions, with which they are unable to agree. I need hardly add that the discovery since the publication of the "Tanganyika Problem" of the Medusa *Limnocnida tanganicae* in Lake Victoria has dealt a further blow to Mr. Moore's theory.

As regards the origin of this Medusa, recent palæontological discoveries afford a much more rational explanation of the presence in Tanganyika of a Cœlenterate of unquestionably marine derivation. The highly important finds of fossils between the Niger and Lake Chad by the English and French officers of the Boundary Commission, which have been reported upon by Prof. de Lapparent, Mr. Bullen Newton, and Dr. Bather, have conclusively established the existence of Middle Eocene marine deposits over the Western Soudan, and the Egyptian and Indian character of these fossils, as well as of others previously obtained in Cameroon and Somaliland, justifies the belief in a Lutetian (Middle Eocene) sea extending across the Soudan to India. In fact, as stated by Mr. Newton, the palæontological evidence seems to prove that the greater part of Africa above the equator was covered by sea during part of the Eocene period. On this sea retreating northwards, after the Lutetian period, Medusæ became land-locked and gradually adapted themselves to fresh water: they had not far to travel to find themselves in what are now the Nile lakes, and later, through the changes which Mr. Moore himself has shown to have taken place in the drainage of Lake Kivu, they were easily carried into the Tanganyika—probably at no very remote time—and maintained themselves to the present day. I understand that the Medusa reported from Bammaku, Upper Niger, in 1895, but still undescribed, has been re-discovered by Budgett, and is now being studied. Should it prove to be related to the Tanganyika species, it would also have to be regarded as a relic of the same Eocene sea, and it would add further support to the very simple explanation which I have ventured to offer of a case which seemed so tremendously puzzling in our previous state of ignorance of the geological conditions of Africa between the equator and the tropic of cancer.

As explained by Prof. Cornet, Tanganyika has been until very recent times without an outlet. The Lukuga, which drains into the Congo, was only formed after Lake Kivu became, owing to volcanic eruption, a tributary of the Tanganyika through the Rusisi River. The greater or less salinity of the water of a lake without an outlet is a matter of course, and therefore Tanganyika was for a long time a salt lake. Its water is still, Mr. Moore says, somewhat salt. No wonder that the Cichlids, which elsewhere in Africa show no aversion to such conditions, and which somehow or other contrive to settle into isolated waters, should have been among the first inhabitants of the lake, where, without having to face competition with other types of fishes, they throve and became differentiated into a multitude of genera. When the hydrographical conditions changed and the water gradually lost its salinity, first on the surface and later at greater depths, an influx of other forms of fish-life (Polypterus, Characinids, Cyprinids, Silurids, &c.) penetrated into the lake, some from the Nile system through the Rusisi, others from the Congo up the Lukuga. This explains well enough the character of the Tanganyika fish-fauna. The Cichlids, the oldest inhabitants of the lake, nearly all belong to endemic species, many of which constitute genera represented nowhere else; whilst the fishes of other families, later immigrants, all belong to widely distributed genera, and several of them even to species also found either in the Nile or in the Congo, or in both these river-systems.

The other theory is that the Cichlids have originated as fresh-water fishes in Eocene times in America and have crossed the Atlantic by a bridge which then connected South America with Africa. This is the explanation given by Dr. Pellegrin. He admits that we have no indication of any near allies of these fishes before the Middle Eocene (Green-River beds of North America), and, basing his statement on the last edition of Prof. de Lapparent's "Traité de Géologie" (1900), he says it seems to be beyond doubt that during the Lutetian period, which immediately followed that at which the earliest Cichlids were known to live in the fresh waters of America, a vast continent extended between South America and Africa. Should this have really been the case, the question of the distribution of the Cichlids could be regarded as settled. But I cannot satisfy myself that there is any geological evidence to support this view.

This third hypothesis has this advantage over the two others, that it does not postulate any land-areas in late Eocene or Miocene times, for which there is at present no sufficient evidence, nor a præ-Tertiary and marine origin for the family Cichlidæ, which is wholly improbable and receives no support from palæontology.

On the other hand, it is undeniable that the hypothesis of a South Atlantic land communication in the Eocene has much in its favour, and when this is really established all difficulty in explaining the distribution of the Cichlidæ will have disappeared. In the meanwhile, to use an appropriate metaphor, we must not construct bridges without being sure of our points of attachment, otherwise they are liable to collapse as geological knowledge progresses.

THE MASTACEMBELIDÆ.—At present we are acquainted with thirty-eight species of Mastacembelus: fourteen from the Indo-Malay region, one from Syria and Mesopotamia, and twenty-three from Tropical Africa. The distribution of these fishes, the fossil remains of which are still unknown, has probably once been a continuous one, climatic and hydrographic conditions possibly accounting for the present discontinuity. We have no data from which to decide whether the Mastacembelids first appeared in Asia or in Africa, or simultaneously in both parts of the world, as is quite possible on the assumption that the family originated in the Eocene sea extending from the Western Soudan to India.

This concludes our review of the affinities and past history of the principal fresh-water types which characterise the present African fish-fauna. We have endeavoured to show that a Tertiary land connection between Africa and South America is not absolutely necessary to explain the many points of agreement between the fresh-water fishes of these two parts of the world, as has been postulated by many writers. Besides, there are still some who hold, as does Prof. G. Pfeffer—whose interesting essay on the zoogeographical conditions of South America, from the point of view of lower vertebrates, appeared after this Address had been written—that a former subuniversality of distribution will afford a solution to many of these problems without necessitating such a land-connection, as exemplified by the past distribution of the Pleurodiran Chelonians. In this review we have summarised many previous hypotheses and added a few, but in every case with a feeling of dissatisfaction, fully realising, as we do, the futility of speculations in the present state of the two great branches of knowledge, geology and palæontology, on which the solution of these questions must ultimately rest.

We may now pass on to the realm of facts, and survey in the briefest manner the waters of the great continent as they appear after the many discoveries which have of late so greatly increased our knowledge of the African fishes.

In the present state of our knowledge of the fresh-water fishes Africa may be divided into five sub-regions, the discussion of the further subdivision of which would exceed the limits of this Address:—

(1) The North-Western Sub-region, or Barbary, and the Northern Sahara, properly forming part of the Palæarctic region.

(2) The Western-Central Sub-region, with all the great rivers and lakes, extending to the Nile Delta and the mouth of the Zambesi, for which the term Megapotamian Sub-region has been suggested to me by Dr. Sclater.

(3) The Eastern Sub-region—Abyssinia, with the upper tributaries of the Blue Nile, and the countries east of the Rift Valley and north of the Zambesi.

(4) The Southern Sub-region—all the waters south of the Zambesi system.

(5) Madagascar.

The smaller islands of the Indian Ocean have a fresh-water fish-fauna so insignificant that they may be entirely neglected in a broad division of the African region.

I. THE NORTH-WESTERN SUB-REGION.

In its deficiency in rivers of permanent flow Barbary has much in common with South Africa, and these two parts of Africa in their fish-fauna present a somewhat analogous example to that on which the now exploded theory of bipolarity was founded. Swelling to foaming torrents in the rainy season or after a storm, reduced to series of pools connected by tiny streams at other times, the watercourses are evidently unsuited to fish-life; and it is not surprising that, apart from a certain number of forms adapted to live in stagnant, often strongly saline, waters, the fishes should be so few in kind. But they make an interesting assemblage, in which it is easy to discover forms unmistakably suggestive of the præ-Pliocene times when the sea had not burst through the Straits of Gibraltar, mixed with others of decidedly Africo-Indian or Oriental affinities.

The number of species from inland waters, whether fresh or salt, hitherto recorded from this part of Africa, amounts to thirty or thirty-one only. Of these thirteen are Cyprinids, which may all be regarded as of northern or eastern immigration. Four of the Barbels show European affinities, one of them being found also in Spain, whilst the seven others belong to a section of the genus largely represented in Southern Asia and East Africa, but only known in West Africa from Cameroon. A species of Varicorhinus, recently discovered in Morocco, has similar affinities, the genus being known from South-Western Asia, Abyssinia, and Lake Tanganyika. A small somewhat aberrant species of the South-Western Asian genus Phoxinellus has been described from the Algerian Sahara, whilst an Alburnus from the Tell (originally placed in the genus Leuciscus) is also the sole representative in Africa of a genus inhabiting Europe north of the Pyrenees and

Alps and South-Western Asia. With two exceptions, all the Cyprinids are confined to the northern watershed of the Atlas, in which varieties of our River Trout and our Stickleback also occur; but *Barbus callensis* and the Phoxinellus occur also in the Algerian and Tunisian Sahara, showing that, as in other groups of animals, no sharp delimitation can be drawn between the Palæarctic and Æthiopian regions of Barbary.

Of three Cyprinodonts one, from the high plateaux, inhabits also Spain; another, more generally distributed, is known from Sicily, Syria, and North-East Africa; whilst the third, remarkable for the absence of ventral fins, is monotypic of a genus named Tellia—a misnomer, as it is not found in the Tell, but on the high plateaux of Algeria, at altitudes of from 2000 to 3000 feet, not 8000, as stated by Danbeck.

Three Cichlids are known from the Northern Sahara, one, a Tilapia, being restricted to Eastern Algeria and Tunisia, whilst the two others, a Hemichromis and a Tilapia, extend to Lower Egypt, and are besides widely distributed in Tropical Africa. The Cichlids, along with the Cyprinodon, the Barbus, and the Phoxinellus mentioned above, are often ejected by artesian wells, and the fact has given rise to much discussion. The latest investigator of this phenomenon, the distinguished engineer, M. George Rolland, confirms the opinion, expressed by the late Sir Lambert Playfair and M. Letourneux in 1871, that these fishes normally live and breed in the lakes and wells exposed to air and light, and that their presence in the underground sheets of water with which the lakes communicate is merely an episode, and as it were an incident in the voyages which they undertake from one opening to the other. There is therefore no justification for the term "realm of the Trogloichthydæ" which has been proposed by Dambeck for North-West Africa.

The other fishes which complete the list are of direct marine derivation, as the anadromous Shad and the catadromous Eel and Grey Mullets, or such as have recently adapted themselves to permanent existence in fresh water, like the Syngnathus discovered by Sir L. Playfair, the Atherina, which occurs also in various fresh-water or brackish lakes in Southern Europe and Egypt and in the Caspian Sea, two Gobies and a Blenny, the latter being also known from fresh waters in the South of France and in Italy. The occurrence of an otherwise strictly marine species of Blenniids (*Cristiceps argentatus*) in the fountain of Ain Malakoff, in the high plateaux of Algeria, rests on the testimony of a naturalist of Algiers and needs confirmation.

II. THE MEGAPOTAMIAN SUB-REGION.

The Nile, the Niger, the Gambia and the Senegal, the Congo, and the Zambesi, with their numerous Mormyrids, Characinids, Silurids, and Cichlids, have much the same general character, which points to many of the generic types having radiated from a common centre of origin, no doubt in those great central lakes which are believed to have existed in Middle Tertiary times. Lake Chad, the ichthyic fauna of which was until quite recently unknown, represents the dwindling remains of a larger basin which communicated until comparatively recent times with both the eastern and western river-systems, thus accounting for the great resemblance between the fishes of the Nile and those of the rivers of the Atlantic watershed north of the Cameroons, 46 species out of 101 known from the Nile (without the great lakes by which it is now fed) being also found in the Niger, the Senegal, or the Gambia, or in all three, and most of these have been recently found in Lake Chad and the rivers emptying into it. The collection made in Lake Chad by Captain Gosling, and sent by him to the British Museum, contains representatives of twenty-four species, all of which were previously known from both the Nile and the Niger, thus strikingly confirming conclusions arrived at from a study of the fauna of those two river-systems. Collections sent to the Paris Museum by the Chevalier and Decorse Mission, and worked out by Dr. Pellegrin, add twenty-five species to the above number, two described as new, two Nilotic, eight West African, five Congolese, the rest being common to the eastern and western river-systems. The Congo differs more considerably, and must therefore have been separated from the Nile-Chad-Niger for a longer period, only 15 out of its 265 species (excluding the Tanganyika) occurring also in the Nile, and eleven in the Chad. When we reach the district of the sources of the Congo, the so-called Katanga district, we find a mixture of Congo and Zambesi forms, which points to a former reversal of the drainage of parts of the elevated dividing range. Lake Mwero belongs to this district; although so near to Lake Tanganyika, it has no fish in common with it except a few of very wide distribution. Lake Bangweolo, also in the same district, is said to swarm with fishes, Silurids and Cichlids especially, but they have never been collected. The Zambesi, so far as it has been explored at present, is the poorest in fishes of the great rivers, and it differs from the others in one important point—the absence of the Polypteridæ. The great lakes differ considerably in their fishes from the river-systems into which they drain.

As pointed out eleven years ago by Prof. Gregory, the system of the head waters of the Nile must have been very differently arranged in times geologically quite recent. This is proved by what we know of the great lakes north of Tanganyika. Thus, of the species known from Lake Victoria, barely one-fourth occur also in the Nile, the rest being mostly endemic; whilst Lake Rudolf, which has now no communication with the Nile, has four-fifths of its species in common with that system. Lakes Albert and Albert Edward are very insufficiently explored and have only yielded a few species, one-half of which are Nilotic. Two fishes, Cyprinids, are all we know from Lake Baringo, one being a widely distributed Nile species, the other an East African. We must conclude from these data that Lake Victoria has long been isolated, whilst Lake Rudolf has until very recently been in communication with the Nile.

Lake Tsana, which is now the source of the Blue Nile, has recently yielded a large collection of fishes, showing a great variety of Cyprinids, either endemic or identical with species occurring in the eastern watershed, and closely allied to those of Palestine, but with no special Nile affinities. The discovery of a Loach (Nemachilus), the first known from Africa, points to an immigration from the Jordan, probably through the old Erythrean Valley. The only species which Lake Tsana has in common with the Nile (*Tilapia nilotica*) occurs also in the Hawash and in the Jordan.

From the vastly increased information we now possess of the fishes of the Nile-system, we are justified in believing in great changes in the hydrography of this part of Africa. The fishes of Lake Tsana would support Prof. Gregory's conclusion as to a communication with the Jordan through a river running along what is now the Red Sea, whilst those of the Lower Nile point to a direct communication between the latter and the Jordan, as advocated by Prof. Hull, migrations along two distinct channels having taken place at a time when the Mediterranean did not extend so far to the east as it does at present, and the Indian Ocean had not penetrated into the Erythrean Valley. A better knowledge of the fishes of Egypt has disposed of Prof. Gregory's arguments against a former communication between the Lower Nile and the Jordan.

The Nile in its widest sense, but without the great lakes, has 101 species, not including those that enter the sea: twenty-seven do not extend north of Khartoum, whilst only six are restricted to the river below the First Cataract. The most important additions made since Dr. Günther's account of them in "Petherick's Travels" are several Mormyrs, Barbus, and Synodontis, three Cichlids, a Xenomystus, a Nannæthiops, a Discognathus, a Barilius, a Chiloglanis, a Fundulus, an Eleotris, and the remarkable genera Physailia, Andersonia, and Cromeria, the latter the type of a new family.

Thanks to the collections made by Sir Harry Johnston and Col. Delmé Radcliffe, with the help of Mr. Doggett, and by M. Alluaud, supplementing those of Dr. Fischer, we may now draw up a list of twenty-five species from Lake Victoria. The comparative scarcity of animal and vegetable life in this great lake perhaps precludes expectation of a great increase in the number of species in the course of further exploration. Most of the species are endemic, and among the most remarkable types may be mentioned a Discognathus, a Mastacembelus (probably the fish noticed by Grant as a Stickleback), and a peculiar genus of Cichlids, Astatoreochromis. No Polypterus has yet been found.

Lakes Albert and Albert Edward, recently visited by Mr. Moore, have furnished examples of nine species, mostly Nilotic in character, the most interesting being a Petrochromis, on account of its close affinity to a Tanganyika species.

Lake Rudolf, as stated above, differs hardly from the Upper Nile, only three of its sixteen species being indicative of immigration from the East. Not a single form is endemic.

The Senegal must have been very thoroughly explored by Dr. Steindachner thirty-five years ago, as a large collection made a few years since by the late M. Delhez has not resulted in a single addition to the list of species. The Gambia, on the other hand, is now much better known than it was, thanks to the two visits of the late Mr. Budgett, to whom we owe the discovery of two species. But it is the Niger which, through the collections made by Dr. C. Christy, the late Captain G. F. Abadie, Mr. Budgett, and especially Dr. Ansorge, has been productive of the most important additions to our knowledge. The most striking discoveries are the type of a new family, Phractolæmus, since re-discovered in the Ubanghi, and Polycentropsis, the first representative of the Nandidæ in Africa. Leaving aside species entering the sea, we now know fifty-four species from the Senegal, forty-one from the Gambia, and ninety-six from the Niger, the lower course of the latter being the most productive. A remarkable feature of these rivers is the comparative paucity of Cyprinids, and the total absence in the first two of the genus Barbus, which also appears to be absent from the Chad basin.

Our knowledge of the piscine inhabitants of the rivers flowing into the Atlantic between the mouths of the Gambia and of the Niger has also made considerable progress. The fishes of Liberia, collected by Dr. Büttikofer, have been described by Dr. Steindachner, and those of the Gold Coast, collected by the late Mr. R. B. Walker, have been reported upon by Dr. Günther. Sixty-seven species are on record from this district, twenty-four of them being endemic.

Further South, North Cameroon has yielded several additions, for a knowledge of which we are indebted to Dr. Lönnberg, whilst South Cameroon, together with the Gaboon district, has been diligently explored by Mr. G. L. Bates, with the result that a great number of new species have been brought to light. This part of Africa is specially interesting from the fact that its rivers interlock with the head waters of the Sanga, which belongs to the Congo basin, and, the fishes being mostly the same in both watersheds, in that district, a sort of passage is established between the Gaboon and Congo faunas. Among the most remarkable forms discovered by Mr. Bates we may mention the genera Microsynodontis, Allabenchelys, and Procatopus. Since Dr. Sauvage reported, twenty-five years ago, on the fishes of the Ogowé, a small collection has been made by the late Miss Kingsley, and described by Dr. Günther, and a number of new species have been characterised by Dr. Pellegrin. The number of species now known from this part of Africa amounts to eighty-seven for South Cameroon and the Gaboon, and fifty-four for the Ogowé. Very curiously, among them we miss Polypterus and Calamichthys, which occur in the Lower Niger and Old Calabar, and again in the Chiloango—a remarkable instance of discontinuous distribution, which cannot be accounted for by physical conditions, so far as we are acquainted with them.

The Congo system (exclusive of Lake Tanganyika), from which only about ninety species of fishes were known ten years ago, proves to be far richer than any other, for, incompletely explored as it still is, it has already furnished examples of 265 species, forty-five of which have been added since the publication of the work "Les Poissons du Bassin du Congo" in 1901. In fact, every collection made even in its most accessible parts adds new species to the list, and many of its rivers have never yet been fished for scientific purposes. No doubt we do not know more than two-thirds of the fishes of the Congo. The riches in Mormyrids, Characinids, Silurids, Cichlids, Mastacembelids, is something surprising, not only in the number of species, but also in their extraordinary variety of structure; and as many as seven species of Polypterids, out of the eleven that are now known, occur in this river-system. With the exception of the Cromeriidæ and Nandidæ, all the families known from the sub-region have representatives in the Congo.

Lake Tanganyika, now forming part of the same hydrographic system, has a somewhat different fauna, consisting mainly of Cichlids, to which we have specially alluded in an earlier part of this Address. But there are, in addition, a number of Silurids and Cyprinids, a few Mastacembelids and Characinids, a Cyprinodont, and a Polypterus. The latter belongs to a species otherwise restricted to the Congo, and of the four Characinids two are Congo and two are Nile forms. The total number of Tanganyikan species of fishes amounts to eighty-five, but, no doubt, many more await discovery. As I pointed out in reporting on Mr. Moore's second collection, I have reason to think that we do not know more than half the species of fishes inhabiting this extraordinary lake. The collection which has just been brought home by Mr. Cunnington will greatly add to our knowledge. I may here mention that Mormyrids, which were believed to be absent from Tanganyika, are therein represented by two species.

Lake Rukwa has recently been explored by Dr. Fülleborn, but the fishes, which have been referred to eleven species, belonging to widely distributed genera, have not been studied with a sufficient comparison-material: they appear to be mostly endemic forms.

Lake Mwero has representatives of fourteen species, five of which are endemic, the remainder being found also in the Congo or in the Zambesi, or in both.

The Zambesi, so far as we know it—and its upper parts have scarcely been explored—appears rather poor in fishes, only forty-one species having been recorded. All the genera are also represented in the Congo and in the Nile. Seven of the Zambesi species occur also in Lake Nyassa and the Upper Shiré, whilst in the present state of our knowledge twenty-seven species, mostly Cichlids, may be regarded as endemic to the lake and the Upper Shiré. It is perfectly clear, however, that Lake Nyassa differs far less from the Zambesi than Tanganyika does from the Nile or Congo; and, although the Cichlids are likewise represented by some remarkable genera, they cannot compare for variety with the other great lake the fauna of which has been such a surprise. Both the Zambesi and Lake Nyassa lack representatives of the Polypteridæ.

About forty-five years ago a collection of fishes was made in Lake Ngami, and twelve species were described in a very unsatisfactory manner by the late Count F. de Castelnau; unfortunately the types of these species are lost, and it is difficult to form an idea of their affinities. We know, however, that the lake, which is now rapidly drying up, was then inhabited by a Mormyr, a Clarias, a Characinid, and several Cichlids.

The rivers of Angola have been but imperfectly explored. They have yielded a number of Cyprinids and Cichlids, a few Silurids, Mormyrids, and Cyprinodontids, and the type of the remarkable genus Kneria, the second species of which inhabits East Africa.

III. THE EASTERN SUB-REGION.

As was mentioned in the beginning of this Address, latitude goes for little in the distribution of fish-life. This is proved by the very marked difference in general character of the fish-faunas of Abyssinia and Africa east of the great Rift Valley as compared to the Nile and Central and West Africa. No Polypterids or Mastacembelids, few Mormyrids, Characinids, and Cichlids, but a great number of Cyprinids, mostly Barbus, characterise this sub-region. Omitting catadromous forms, the list of fishes consists of one Lepidosirenid, six Mormyrids, eight Characinids, seventy Cyprinids, twenty Silurids, one Kneriid, six Cyprinodontids, and seven Cichlids.

Lake Tsana, with the upper affluents of the Blue Nile, differs very strikingly in its fishes from the Nile, with which it has only two species in common, a Silurid (*Bagrus docmac*), and a widely distributed Cichlid (*Tilapia nilotica*), which occurs also in the Hawash and in

Palestine. Nearly all the fishes are Cyprinids, mostly of the genus Barbus, which bear close affinity to Syrian types, as does also the recently discovered Loach (*Nemachilus abyssinicus*), so far the only known African representative of that Europæo-Asiatic group. The single species of the Cyprinid genus Varicorhinus is also suggestive of South-Western Asia, although a second African species inhabits Lake Tanganyika, and a third has lately been discovered in Morocco. Another Cyprinid genus, Discognathus, which is widely distributed over Southern Asia, from Syria and Aden to Burma, is represented by two species, whilst others are known from Abyssinia and East Africa (Gallaland, Kenya, and Kilimandjaro districts), and one each from the Nile and Lake Victoria. A remarkable negative feature is the absence, as in Syria, of Labeo, a genus abundantly represented in the Nile, Senegal, Niger, Congo, and Zambesi, and more scantily in East and South Africa. It is a suggestive fact, tending to show that, somehow or other, Lake Tsana has only comparatively lately been in communication with the Nile, that the Varicorhinus and several of the Barbus are common to this lake and to some of the rivers of the eastern watershed; whilst not one of the Cyprinids occurs also in the Nile. The main stream of the Blue Nile has only been explored up to Rosaires, but the fishes obtained in that part of the river do not in any way differ from those of the Upper Nile.

The chief character of the rivers east of the Rift Valley is, as already stated, the number of species of Barbus. The Cyprinids are further represented by a few Labeo and Discognathus, by a Neobola, and by the only African representative of the Indo-Malay genus Rasbora. The Mormyrids are represented by six species only. The few Characinids belong to the genus Alestes and to its near allies Micralestes and Petersius. Of the twenty Silurids, some are widely distributed species, others are common to the Nile or to the Zambesi, whilst among the species with a restricted habitat we note a Physailia, two Bagrus, two Amphilius, a Synodontis, and two Chiloglanis—altogether a poor series as compared with other districts of Tropical Africa—and not a single autochthonous genus. A species of the remarkable genus Kneria, a few Cyprinodontids, and a few Cichlids of the genus Tilapia complete what is for a district of that extent, well watered and within the tropics, a very meagre list.

IV. THE SOUTHERN SUB-REGION.

Africa south of the Zambesi system has a poor fresh-water fish-fauna, but this is easily accounted for by the intermittent character of most of its rivers. The list I have drawn up from available data includes only fifty species, seven of which are partly marine. When discussing the distribution of the South African fresh-water fishes eight years ago Prof. Max Weber compiled a list of sixty-four species; but this included a number of truly marine forms, occurring only in estuaries, besides a few of very doubtful determination, which I am obliged to leave out. The majority of the exclusively fresh-water fishes are Cyprinids, viz. seventeen Barbus and three Labeo. Characinids are represented by the widely distributed *Hydrocyon lineatus*, which occurs in the Limpopo, and the newly discovered *Alestes natalensis*, from near Durban. Three Clarias, an Eutropius, a Gephyroglanis, and a Galeichthys, the latter semi-marine, represent the Silurids. The two Galaxias, as distinguished by Castelnau, the most remarkable type of the South African fish-fauna, and the two Anabas, are confined to the south-western district of Cape Colony. A Cyprinodontid of the genus Fundulus has been described from False Bay. Four Gobies and five Cichlids of the genera Hemichromis, Paratilapia, and Tilapia complete the list.

Poor as it is in fishes, the south-western district—the *Erica or Protea district* of Max Weber—derives a special character from the presence of the genera Galaxias and Anabas. The western district is also poor, and has only representatives of three families: Cyprinids, Silurids, and Cichlids; whilst the eastern district, from the Limpopo system and the tributaries of the Orange River to Natal, is the richest, two families, Characinids and Gobiids, being represented, in addition to the three above named. The recent discovery in the Vaal River of a Gephyroglanis, a Silurid genus otherwise known only from the Congo and Ogowe, deserves notice.

Whether the subterranean reservoirs of the Kalahari are inhabited by fishes, as is the case in the Northern Sahara, is still unknown.

Excepting such forms as are believed to have been directly derived from marine types, there is every reason to regard the piscine inhabitants of the fresh waters of South Africa as comparatively recent immigrants from the North.

V. MADAGASCAR.

It is extremely remarkable that this great island, which in most groups of animals shows so many striking features, should in its fish-fauna be one of the most insignificant districts in the whole world. For, if we exclude the numerous Grey Mullets and Gobies, and a few Perches of the genera Kuhlia and Ambassis, which live partly in the sea, and probably mostly breed in salt water, the truly fresh-water fish-fauna is reduced to sixteen species—viz., two Silurids, two Cyprinodontids, one Atherinid, four Cichlids, and seven Gobiids, the latter, no doubt, recent immigrants from the sea. The Silurids belong to two distinct genera, Læmonema, allied to the African Chrysichthys, first discovered in Mauritius, and Ancharius, allied to the marine or semi-marine Arius, and, perhaps, also entering the sea. Of the four Cichlids two belong to a very distinct autochthonous genus, Paretroplus, whilst the two others are respectively referred to the African genera Tilapia and Paratilapia. The two Cyprinodontids belong to the widely distributed genus Haplochilus.

In concluding this sketch, whilst looking back with satisfaction upon the rapid progress which African ichthyology has lately made, and expressing our gratitude to the Governments, institutions, and collectors to whom we owe this progress, we cannot abstain from pointing out how much remains to be done. All the great lakes are insufficiently explored, and Bangweolo has never been fished for scientific purposes, whilst within the limits of this colony an extensive collection from the Upper Zambesi is still a desideratum, and Lake Ngami is drying up without any of its fishes having been secured for study. The fishes of the Congo above Stanley Falls, and of many of its northern and all of its southern tributaries, are still unknown. But it is gratifying to observe the ever-growing interest in this hitherto somewhat neglected branch of zoology, and I may express the hope that the next decade will be productive of even greater results than have been achieved within the last.

NOTES.

WE regret to see the announcement of the death of Prof. Jules Oppert, professor of Assyrian philology and archæology at the Collège de France, renowned for his contributions to astronomical chronology and his works on Chaldea and Assyria.

THE Berlin correspondent of the *Times* announces the death, at seventy-six years of age, of Prof. Franz Reuleaux, who, as author of a number of engineering works and director of the Berlin Industrial Institute, rendered good service to the development of practical and scientific engineering in Germany.

NEW ORLEANS has been suffering from a serious outbreak of yellow fever, but there are now signs that the health authorities are getting the disease well in hand. Up to the end of last week, that is, a period of about four weeks, more than 1000 cases and 171 deaths had been recorded. It is believed that the fever was introduced into the city through fruit vessels arriving between June 1 and June 15 from Central America. All patients have been screened from mosquitoes, and there must now be little danger of infection from them.

THE returns of births and deaths recently issued by the Registrar-General, while in some respects satisfactory, in one are of a disquieting nature. This is with reference to